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CHEMICAL PROGRESS IN THE SOUTH

Chemical Progress in the South

National Research Council
Division of Chemistry and Chemical Technology

CHEMICAL PROGRESS IN THE SOUTH

COMPILED AND EDITED BY

DIVISION OF CHEMISTRY AND
CHEMICAL TECHNOLOGY

National Research Council
J. E. MILLS, Chairman

THE CHEMICAL FOUNDATION, Incorporated
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CHEMICAL PROGRESS IN THE SOUTH: PREFACE

The facts here collected are presented in the hope that some can be found who will make use of them. It is for the reader therefore to determine whether the effort made is worthwhile. In a short time the facts collected will be out of date and this publication forgotten. But if the reader will use the facts presented to accomplish something of benefit, his accomplishment will live on and bear fruit as the years go by, perhaps a hundredfold. The book deals with the present, but if you would read it with an understanding heart, think of the future and translate some of your thoughts into action.

In re-reading the pages the editor is troubled mainly by one feeling. Perhaps he has been too modest in the suggestions made. There is no reason why the South should not build up educational institutions the equal in all respects of the best in the United States. Its industrial expansion should rival that of any section of the country. Its laborers should have equal training and equal capacity and should receive equal pay. Therefore look to the future and plan for big things. Let each individual do his own best to bring to pass the realization of those plans.

Some omissions have doubtless occurred through ignorance, others from necessity. Certain interesting developments could not be described because the owners did not desire any publication at this time concerning the processes involved. In this publication the opinions expressed are the opinions of the individual authors.

The Chairman of the Division of Chemistry and Chemical Technology, of the National Research Council, would express the thanks of the Division and his own thanks to the many who have contributed material for this volume, and to those who have aided by the information furnished, and by suggestions as to the work. Without this coöperation nothing could have been accomplished.

Particularly we would express our sincere thanks for the assistance of Doctor Clarence J. West and Miss Callie Hull of the Research Information Service, of the National Research Council, who have prepared Part V of this volume for publication, and for the generosity of the Chemical Foundation, which has borne the expenses of its publication. The chemists of the nation owe a real debt to Mr. Francis P. Garvan and to the Chemical Foundation for their great contribution to the advancement of chemistry in this country by the aid so often given to the publication of information encouraging the development of chemistry.

Washington, D. C.
June 28, 1930

J. E. MILLS, *Chairman*
DIVISION OF CHEMISTRY AND CHEMICAL TECHNOLOGY
NATIONAL RESEARCH COUNCIL

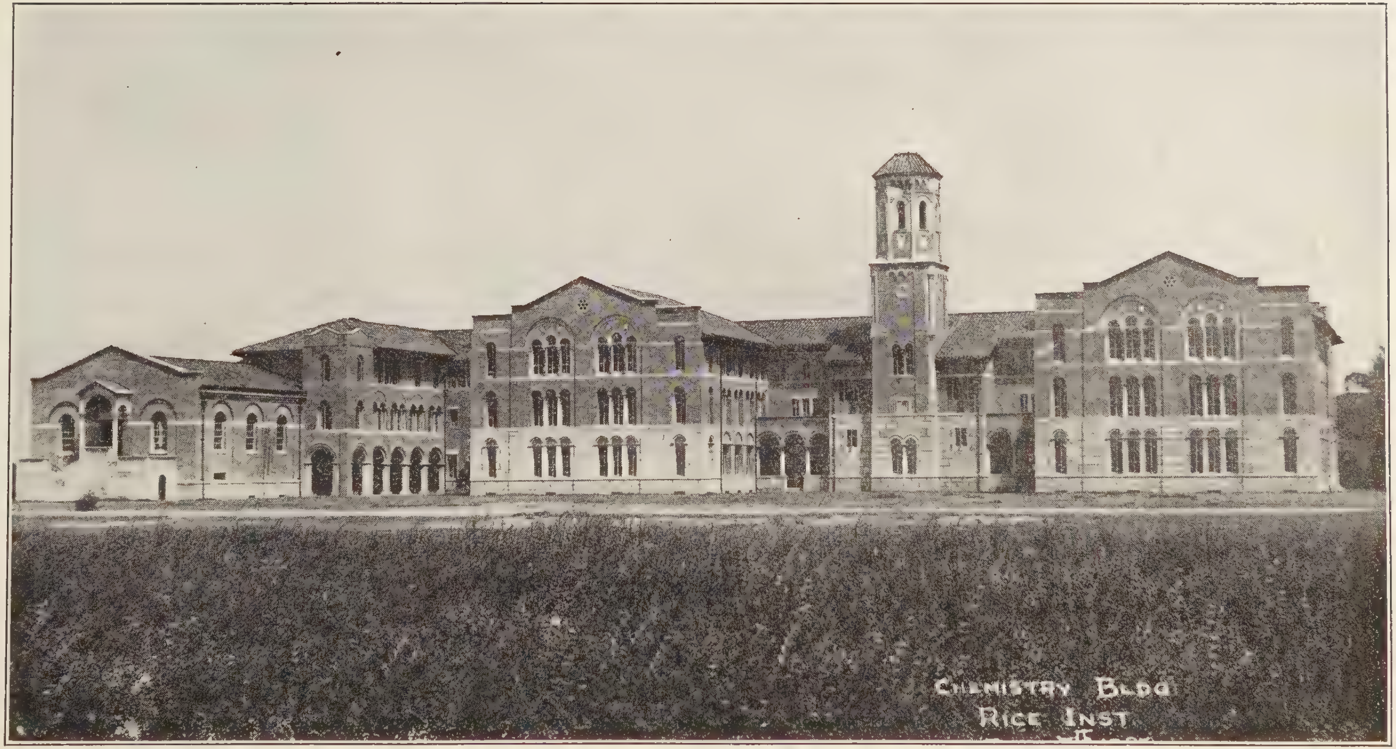
CHEMISTRY BLDG
RICE INST

FIGURE 1.—CHEMISTRY BUILDING, RICE INSTITUTE, HOUSTON, TEXAS. ERECTED 1924

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CHEMICAL PROGRESS IN THE SOUTH

PART I. EDUCATIONAL INSTITUTIONS

PART I

EDUCATIONAL INSTITUTIONS

Foreword

E. Emmet Reid, The Johns Hopkins University, Baltimore, Maryland

Mark Hopkins on one end of a log and a student at the other is said to have constituted a college. This has been proved over and over again in southern schools where there have been able teachers and apt pupils and sometimes little else. In philosophy a school can be run that way, as was demonstrated by Socrates, but if Socrates had attempted to teach Plato chemistry or physics he would not have got far. Poe needed only a sheet of paper and a pencil to write his immortal *Raven* but an astronomer requires a hundred-thousand-dollar telescope to gather the light of a star and other costly instruments to measure it. The teaching of modern science requires a large outlay for apparatus and materials.

Educational institutions depend either on the state or on the surplus wealth of individuals. Before the Civil War there were many southerners in comfortable circumstances but there were scarcely any great fortunes such as had been amassed in the manufacturing centers of the North. The capital of the South, both of individuals and of institutions, was largely swept away by the Civil War. The marvel is that southern institutions have accomplished so much in these sixty years. With their inadequate resources they properly began with courses which were in the greatest demand and which were the least expensive to teach. So it was that languages, philosophy, and mathematics were well developed while chemistry and physics lagged behind. Chemistry is of vital importance in many lines of manufacture and has thrived best where people are industrially minded. The old agricultural South did not realize the need of chemistry.

With the growth of wealth and with the development of manufacturing in the South the sciences have come to take their proper place in the educational scheme and adequate laboratory facilities have been provided. That the young men and women of the South have an aptitude for science is attested by the number of them who have gone to other sections and have become national figures in academic and industrial research.

Chemical research has lagged in the South. To do research one must have laboratory facilities and must not be so burdened with routine teaching that no time or energy is left. The best of the southern institutions have taken care of these conditions and the rest are progressing in that direction.

The example of others is a great incentive. There are quite a number in the South engaged in research but they are scattered over a wide territory and do not come in sufficient contact with each other or with the teachers in other institutions. The one condition for research that is most difficult to provide is adequate library facilities. As this report shows, there are only a few places in the South where such facilities are available.

To remedy a condition the first thing is to ascertain exactly what the situation is. That is the purpose of this report. Its data are from first-hand information; one may weep over them but one cannot doubt them. The actual conditions are presented in such a way that they frequently suggest their own remedies.

CHAPTER I

EDUCATIONAL PROGRESS IN CHEMISTRY

J. E. Mills, National Research Council, Washington, D. C.

The Chairman of the Division of Chemistry and Chemical Technology, of the National Research Council, has undertaken to collect information concerning chemical progress in thirteen southern states—Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

Organization—Property and Funds, Colleges and Universities

In these states there are one hundred twelve accredited (*1*) colleges and universities and nineteen medical colleges (*2*). Fifteen schools of pharmacy are members of The American Association of Colleges of Pharmacy. Six of the thirteen agricultural and mechanical colleges are combined with, or adjacent to, the state universities in the states of Arkansas, Florida, Georgia, Kentucky, Louisiana, and Tennessee. The different states usually maintain separate branch agricultural experiment stations at various points. No attempt was made to study the work of these branch stations.

A good many of the agricultural and mechanical colleges have organized engineering experiment stations for the study and solution of problems affecting the welfare of the State. These stations promise much for the future. Much of the work of these stations will be chemical in its nature.

General data concerning the accredited colleges and universities are given in Table I, Part IV, on STATISTICAL INFORMATION. From the data there shown the thirty-five institutions which lead respectively in number of students, value of property, productive funds, and total receipts exclusive of additions to endowment are shown in Tables I and II herewith. The data given are for the year 1927–28 and have been taken from U. S. Department of Interior, Office of Education, Bulletin No. **38** (1929). The number of students given is exclusive of students in the summer school, extension classes, and correspondence courses. The value of property given includes value of libraries, scientific apparatus, machinery, furniture, and other equipment; value of grounds (including farm); value of buildings (including dormitories) and value of all other property (excluding endowment). Statistics concerning medical colleges which are part of a university are included in the university returns and are not separately shown.

It should be noted that the statistics as reported do not necessarily imply that the total assets of the institution can be obtained by adding

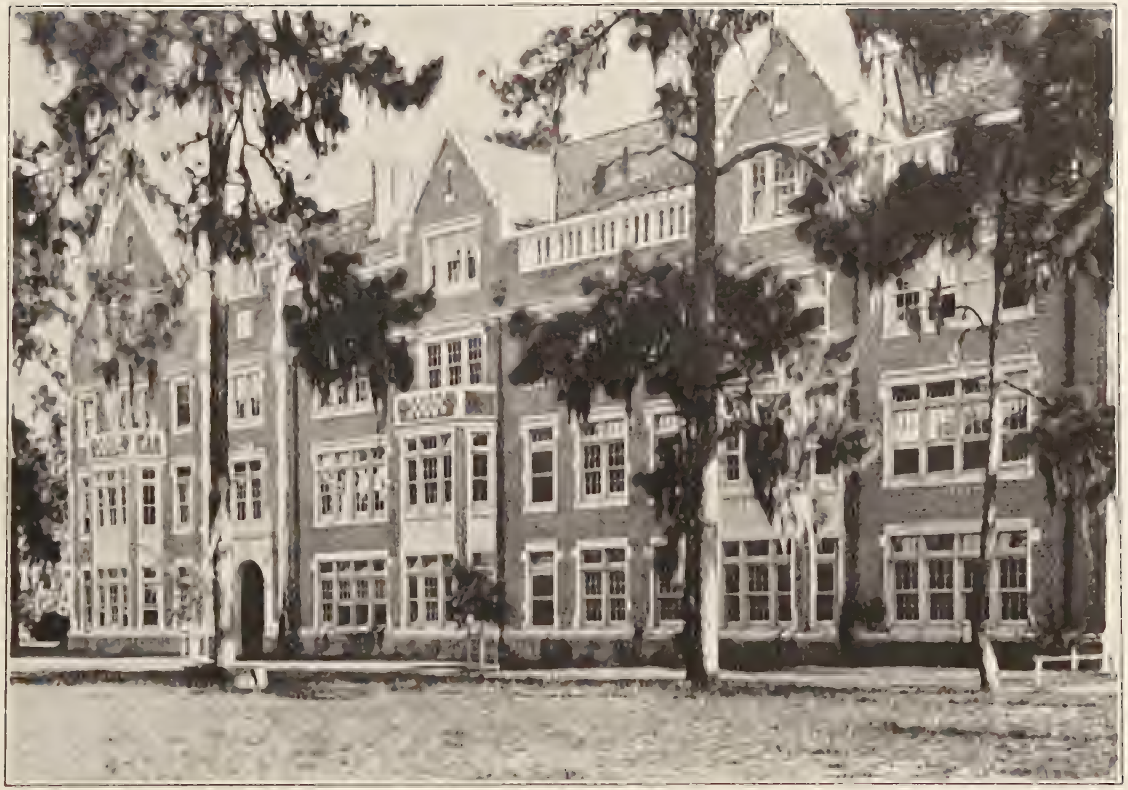

FIGURE 2.—CHEMICAL LABORATORY, UNIVERSITY OF FLORIDA, GAINESVILLE, FLORIDA. ERECTED 1927

TABLE I

Comparative Statistics Concerning Certain Accredited Colleges and Universities in Thirteen Southern States

		Number of students			*Value of property*
1.	University of Texas	6308	1.	Duke University	$21,148,700
2.	University of Oklahoma	5378	2.	University of Texas	10,491,095
3.	Baylor University	3732	3.	Univ. of N. Carolina	7,949,874
4.	Tulane University	3157	4.	University of Tennessee	6,684,088
5.	University of Tennessee	3032	5.	A. & M. College of Texas	6,589,537
6.	University of North Carolina	2889	6.	Louisiana State University	6,419,414
7.	Oklahoma A. & M. College	2860	7.	N. C. College for Women	6,074,367
8.	University of Alabama	2823	8.	Vanderbilt University	5,618,099
9.	University of Kentucky	2791	9.	Tulane University	5,489,473
10.	A. & M. College of Texas	2548	10.	Emory University	4,990,362
11.	Southern Methodist University	2289	11.	University of Florida	4,948,675
12.	University of Virginia	2196	12.	University of Oklahoma	4,320,853
13.	Georgia School of Technology	2178	13.	Southern Methodist University	4,197,345
14.	Louisiana State University	2098	14.	N. Carolina State College	4,129,085
15.	University of Florida	2077	15.	University of Georgia	3,964,110
16.	Winthrop College	2054	16.	Rice Institute	3,926,100
17.	Berea College	1905	17.	Va. Polytechnic Institute	3,683,380
18.	University of Arkansas	1878	18.	University of Virginia	3,478,434
19.	Baylor College for Women	1763	19.	Loyola University	3,361,000
20.	University of Georgia	1726	20.	College of William and Mary	3,110,500
21.	Duke University	1705	21.	University of Kentucky	3,088,799
22.	College of Industrial Arts	1702	22.	Oklahoma A. & M. College	3,073,365
23.	Texas Technological College	1682	23.	Winthrop College	3,056,459
24.	Alabama Polytechnic Institute	1614	24.	Georgia School of Technology	3,029,000
25.	University of South Carolina	1609	25.	Berea College	3,006,612
26.	N. C. College for Women	1564	26.	Florida State C. for Women	2,905,000
27.	N. C. State College	1541	27.	Miss. A. & M. College	2,895,555
28.	Florida State C. for Women	1434	28.	University of Mississippi	2,893,100
29.	Miss. A. &. M. College	1431	29.	University of S. Carolina	2,834,704
30.	University of Louisville	1385	30.	The Citadel	2,614,100
31.	Miss. State C. for Women	1374	31.	Miss. State C. for Women	2,572,450
32.	Texas Christian University	1366	32.	College of Industrial Arts	2,432,037
33.	Emory University	1356	33.	University of Arkansas	2,220,000
34.	Vanderbilt University	1342	34.	Clemson College	2,172,400
35.	Rice Institute	1322	35.	University of Alabama	2,090,861

the total value of the property to the value of productive funds given, since some institutions might invest productive funds in heating plants, dormitories, etc., from which an income can be obtained.

It would have been desirable to show the total annual budget for maintenance but this figure could not be obtained from the statistics given

TABLE II

Productive Funds and Total Receipts of Thirty-Five Colleges and Universities

		Productive funds			*Total receipts exclusive of additions to endowment 1927–28*
1.	University of Texas	$21,060,521	1.	A. & M. College of Texas	$4,059,493
2.	Duke University	20,785,207	2.	University of N. Carolina	3,237,313
3.	Vanderbilt University	10,777,394	3.	University of Texas	2,911,140
4.	Rice Institute	10,500,000	4.	University of Tennessee	2,411,702
5.	Tulane University	8,982,001	5.	University of Oklahoma	2,227,983
6.	Berea College	8,894,739	6.	University of Kentucky	2,216,070
7.	Emory University	4,142,073	7.	N. Carolina State College	2,097,269
8.	University of Virginia	4,061,632	8.	University of Florida	2,096,464
9.	University of Oklahoma	3,200,000	9.	Oklahoma A. & M. College	2,041,598
10.	Southern Methodist University	2,277,402	10.	Va. Polytechnic Institute	1,983,510
11.	Wake Forest College	2,264,150	11.	University of Mississippi	1,966,028
12.	University of Richmond	2,196,996	12.	University of Virginia	1,925,745
13.	University of North Carolina	2,137,648	13.	Duke University	1,850,294
14.	University of Alabama	1,958,989	14.	Miss. A. & M. College	1,707,374
15.	University of the South	1,687,912	15.	Tulane University	1,629,747
16.	Maryville College	1,483,951	16.	Vanderbilt University	1,628,139
17.	Washington and Lee University	1,390,047	17.	Louisiana State University	1,594,471
18.	Centre College	1,249,107	18.	Clemson College	1,586,485
19.	Agnes Scott College	1,051,420	19.	Alabama Polytechnic Institute	1,584,111
20.	Randolph Macon Women's College	1,012,667	20.	N. C. College for Women	1,556,149
21.	University of Chattanooga	1,005,600	21.	Wesleyan College	1,358,869
22.	Randolph Macon College	996,382	22.	University of Georgia	1,343,903
23.	Davidson College	947,508	23.	University of Arkansas	1,304,189
24.	Millsaps College	931,909	24.	College of William and Mary	1,252,998
25.	Birmingham Southern College	910,068	25.	University of Alabama	1,061,965
26.	Transylvania College	819,302	26.	Berea College	1,016,741
27.	Mercer University	735,603	27.	Rice Institute	973,200
28.	Meharry Medical College (Colored)	719,373	28.	Winthrop College	972,503
29.	University of Mississippi	710,153	29.	Florida State College for Women	943,582
30.	Mississippi College	698,917	30.	Texas Technological College	927,655
31.	University of Tulsa	698,827	31.	Virginia Military Institute	927,113
32.	Trinity University	695,032	32.	College of Industrial Arts	877,562
33.	Tusculum College	678,531	33.	Emory University	870,754
34.	Furman University	655,519	34.	Southern Methodist University	833,387
35.	Georgetown College	654,624	35.	Georgia School of Technology	737,216

since funds are not always expended on buildings the same year the funds are received, and subtraction of the amount spent on new buildings from the total receipts, exclusive of additions to endowment, would give figures varying in some cases widely from the annual budget for maintenance.

The figures indicate that a very rapid growth has taken place in the colleges and universities of the South. Large building programs have been necessitated by the increase in the number of students and this fact has made the financial strain on many of the institutions quite great in spite of the increased financial support which they have received.

Nevertheless it is extremely encouraging to note that nine institutions reported for 1927–28 total receipts exclusive of additions to endowment of more than $2,000,000 and twenty-six institutions reported receipts of more than $1,000,000. An institution which receives more than $1,000,000 a year can no longer be regarded as in the proverty-stricken class and can afford to plan in an adequate way for the development of its scientific departments.

Of the one hundred twelve accredited institutions in Table I, Part IV, reporting their total receipts, exclusive of additions to endowment, these receipts were less than $300,000 for fifty-one of the institutions.

Concerning special schools or special courses requiring some training in chemistry the following may be mentioned:

	Years in course	*Number of students 1928–29 (2)*
Medical Schools		
U. of Alabama School of Medicine, Tuscaloosa	2	102
U. of Arkansas School of Medicine, Little Rock	4	158
Emory U. School of Medicine, Atlanta, Georgia	4	191
U. of Georgia Medical Department, Augusta	4	135
U. of Louisville School of Medicine, Louisville, Ky.	4	322
Tulane U. of La. School of Medicine, New Orleans	4	438
U. of Mississippi School of Medicine, Oxford	2	63
Duke U. School of Medicine, Durham, N. C.	4	(Will commence October 1, 1930)
U. of N. C. School of Medicine, Chapel Hill	2	76
Wake Forest C. S. of Medicine, Wake Forest, N. C.	2	54
U. of Okla. School of Medicine, Oklahoma City	4	192
Medical C. of State of S. C., Charleston, S. C.	4	153
U. of Tennessee College of Medicine, Memphis	4	378
Vanderbilt U. School of Medicine, Nashville, Tenn.	4	181
Meharry Medical College, Nashville, Tenn. (Colored)	4	216
Baylor U. College of Medicine, Dallas, Texas	4	356
U. of Texas School of Medicine, Galveston	4	275
Medical College of Virginia, Richmond	4	371
U. of Virginia Dept. of Medicine, Charlottesville	4	243
Schools of Pharmacy		
Alabama Polytechnic Institute, Department of Pharmacy, Auburn		
U. of Florida, College of Pharmacy, Gainesville		
U. of Georgia, School of Pharmacy, Athens		

Louisville College of Pharmacy, Louisville, Kentucky
Loyola U., New Orleans College of Pharmacy, New Orleans
Tulane U. of Louisiana, School of Pharmacy, New Orleans
U. of Mississippi, School of Pharmacy, Oxford
U. of North Carolina, School of Pharmacy, Chapel Hill
U. of Oklahoma, School of Pharmacy, Norman
Medical College of the State of S. C., School of Pharmacy, Charleston
U. of South Carolina, School of Pharmacy, Columbia
Meharry Medical College, Department of Pharmacy, Nashville, Tenn. (Colored)
U. of Tennessee, School of Pharmacy, Memphis
U. of Texas, College of Pharmacy, Galveston
Medical College of Virginia, School of Pharmacy, Richmond

Chemical Engineering

Alabama Polytechnic Institute
University of Alabama
University of Arkansas
University of Florida
Georgia School of Technology
University of Kentucky
Tulane University
University of Louisiana
A. & M. College of North Carolina
University of North Carolina
A. & M. College of Oklahoma
University of Oklahoma
University of Tennessee
A. & M. College of Texas
North Texas Agricultural College
Rice Institute
University of Texas
Virginia Military Institute
Virginia Polytechnic Institute
University of Virginia

Textile

Alabama Polytechnic Institute
Georgia School of Technology
A. & M. College of North Carolina
University of Oklahoma
A. & M. College of Texas
Clemson College
Texas Technological College—Building $150,000, Equipment $100,000

Ceramic

Alabama Polytechnic Institute
University of Alabama
Georgia School of Technology
A. & M. College of North Carolina
Oklahoma A. & M. College—Equipment $8500
A. & M. College of Texas—Equipment $1500
University of Texas—Equipment $5640
Virginia Polytechnic Institute

Petroleum

University of Louisiana
University of Oklahoma
A. & M. College of Texas—Equipment $4500
University of Texas—Equipment $1500

Cottonseed

A. & M. College of Texas—Equipment $20,000

Sugar

University of Louisiana (Audubon Sugar School)—Equipment $150,000

Rayon and Pulp

Virginia Polytechnic Institute—Equipment $4000

Tobacco

Duke University—Equipment $8000
Liggett and Meyers Research Foundation with annual budget of $28,000

Metallurgy

University of Alabama
University of Kentucky
University of Texas

Buildings and Equipment for Chemistry

In addition to the special schools and facilities mentioned, data furnished by the heads of the departments of chemistry concerning the chemical laboratories and chemical departments are given in Table III. In some cases the department heads stated that estimates were given. It will be seen that 20 chemical laboratories have been authorized, built, or materially enlarged since the beginning of 1924. These include four buildings planned entirely or mainly as chemical laboratories but now used in considerable part by other sciences (Southwestern, Texas Technological College, Washington and Lee University, College of William and Mary). Thus as regards the larger colleges and universities, the building, or space, devoted to chemistry is fairly adequate at the present time except as noted below:

The Universities of Arkansas, Georgia, and South Carolina need new buildings and the laboratory started at the Agricultural and Mechanical College of Texas should be completed. The Universities of Louisville and Oklahoma, the Oklahoma Agricultural and Mechanical College, and the Virginia Polytechnic Institute now need additional space for their departments of chemistry. Continued growth will necessitate additional space in other laboratories now fully utilized.

Several of the medical colleges expressed the need for additional chemical laboratory facilities.

About 1905 the cost of a chemical laboratory and permanent equipment in the South was around $4.00 per square foot of floor space. Now it has

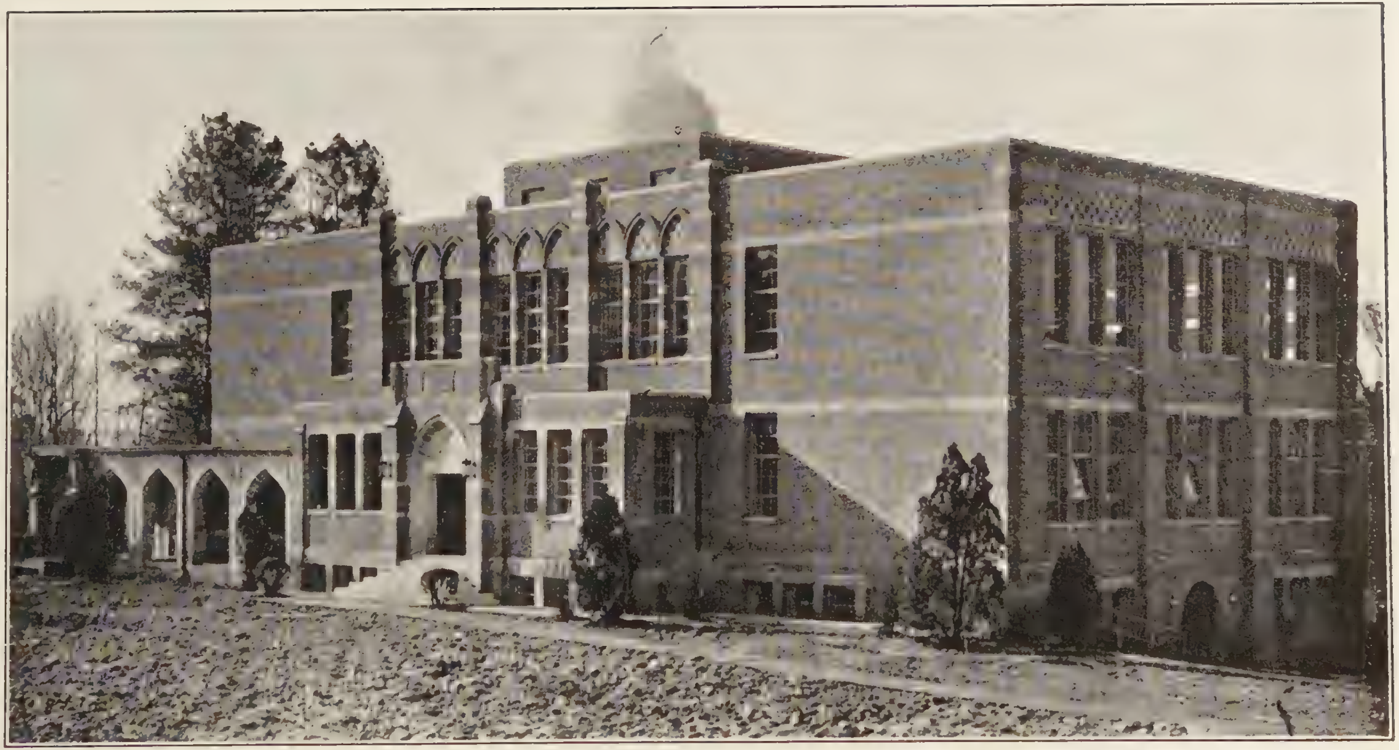

FIGURE 3.—CHEMICAL LABORATORY, UNIVERSITY OF RICHMOND, RICHMOND, VIRGINIA. ERECTED 1927

TABLE III

Chemical Laboratory Buildings and Equipment

	Date	Sq. ft. floor space	Cost of bldg. and per. equip.	Non-per. equip.	Pay-roll	Budget	Lab. fees	Students in chemical courses
1. U. of Texas	Bldg.	100,957	$910,000	$55,000	$69,540	$26,000	$10,500	1815
2. Rice Institute	1924	65,000	650,000	75,000	....	17,500	13,100	460
3. Duke University	Bldg.	57,000[1]	650,000	23,000	25,000	12,000	4,800	456
4. U. of N. C.	1925	55,000	425,000	50,000	44,700	17,700	17,700	500
5. Louisiana State	1925	75,000	420,000	35,000	....	....	....	953
6. U. of Florida	1927	31,890	390,000	30,000	33,200	24,951	10,000	737
7. U. of Oklahoma	1916	33,800	350,000	50,000	34,900	18,000	18,000	1000
8. U. of Mississippi	1921	55,000	325,600	15,000	19,200	4,000	3,000	499
9. U. of Tennessee	91–29[5]	46,000	300,000	30,000	25,900	10,000	17,500	806[8]
10. Ala. Poly. Inst.	1930	43,000	286,000	16,000	....	....	None	1100[8]
11. Univ. of Ky.	10–26	45,000	272,021	15,140	29,400	9,400	None	575
12. Miss. A. & M.	1912	35,000	250,000	65,000	14,400	15,000	....	550
13. U. of Alabama	1927	40,000	225,000	45,000	25,900	15,000	15,000	1125
14. N. C. State Coll.	1910	36,612	225,000	35,000	....	....	....	819
15. Emory U.	1925	30,486	200,955	10,000	12,000	3,500	4,850	400
16. Vanderbilt U.	1906	60,000	200,000	42,500	30,500	10,500	16,250	650
17. Va. Polytechnic	1927	37,000	190,000	19,300	28,810	4,700	2,400	1200
18. Tulane U.	94–08[6]	27,700	190,000	60,000	22,000	....	....	500[8]
19. Georgia Tech.	05–25	35,000	175,000	7,500	34,000	5,000	None	780
20. U. of Richmond	1927	20,000	165,000	16,000	7,700	3,500	2,500	208[8]
21. U. of Virginia	1917	30,000[2]	160,000	30,250	66,100	19,439	....	538
22. A. & M. of Texas	1929	15,540	141,500	27,681	45,279	6,000	5,000	1388
23. Okla. A. & M.	1919	25,700	131,000	33,000	38,550	5,400	9,100	1270
24. Clemson College	90–00	24,000	105,000	22,475	15,400+	6,020+	None	679
25. U. of Louisville	1924[4]	10,342	90,000	23,000	25,000	8,000	None	756[8]
26. U. of Arkansas	1905	11,000[3]	44,000	36,000	27,980	9,455	5,734	675
27. Wake Forest	1888	15,000	42,000	13,738	11,200	3,300	2,625	231
28. Davidson College	1899	6,400	40,000	6,000	8,100	1,000	1,200	156
29. U. of Georgia	1905	22,500	35,800	7,500	13,950	3,500	3,000	709
30. Southwestern	1925	42,000	366,548[7]	16,000	8,200	3,090	3,090	117
31. Texas Tech.	1929	50,000	280,000[7]	25,000	20,000	3,000	2,000	500
32. Wash. & Lee U.	1924	26,000	250,000[7]	5,000	13,050	2,200	2,262	185
33. William & Mary	1927	25,000	260,000[7]	20,000	11,250	4,000	4,000	450

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[1] When this building is completed 11,450 sq. ft. of additional floor space in the science building will be used for chemistry in the Women's College.

[2] A new wing giving 13,000 sq. ft. of additional floor space and to cost $105,000 is under construction.

[3] Uses half of another building (11,260 sq. ft.—$^{1}/_{2}$ value = $35,000).

[4] Remodeled 1924.

[5] Uses two buildings.

[6] Remodeled 1908.

[7] Only partly used for chemistry.

[8] Individual students taking chemistry.

increased to about $8.00 to $10.00 per square foot. No attempt was made to ascertain building costs in other sections of the country. Fifty square feet of floor space and above for each student per course in chemistry seems to be considered adequate. When the amount is decreased much below 50 square feet a desire for additional space is generally expressed. At about 30 square feet of floor space per student per course need for additional space seems to be imperative even when there is little provision for research.

The equipment is not as yet up to the standard of the buildings but is generally fairly adequate.

Stretching the Value of a Dollar

In nearly all of the chemical laboratories in the South the compelling need to obtain the full value for every dollar expended is apparent. Much planning and much ingenuity have gone to effect some saving without corresponding sacrifice.

In one laboratory the laboratory desks had been made by students in the woodworking shops, the sinks were cast by students in the foundry, and even the electric hot plates were of home manufacture. If attention had not been called to these facts they would have escaped notice.

Another laboratory, kept beautifully clean—the cleanest laboratory the writer has ever visited, when laboratories in which a similar large amount of work is done are considered—contained a good machine shop. In this shop many excellent and really beautiful pieces of apparatus had been constructed for expediting routine analyses. Beautiful red cherry wood had been used and exquisitely polished and finished, and many improvements made permitting both accuracy and speed. Such apparatus could not be bought.

In constructing the chemical laboratory at Emory University use has been made of the fact that snow seldom falls in that locality to secure ten additional research rooms under the roof of the building. For this purpose the roof of the laboratory was suddenly interrupted on each side by a "trench," not noticeable from the campus level unless attention had been called to the construction. Adequate provision is made for taking care of rainfall. The "trenches," or passages, thus provided give entrance to the research laboratories and at the same time allow adequate light to reach the rooms.

Painful economy cannot always be recommended, but economy without pain—that is an achievement.

Student Enrolment

In seven institutions the number of students in the various courses in chemistry exceeds 1000 and in the twenty-four largest institutions the average number is 838.

Budget for Chemistry

The budget allowance for each student per course in chemistry (including all of the eighty-eight institutions from which reports were received) is most variable, extending from $2.50 per student to $30.00 and

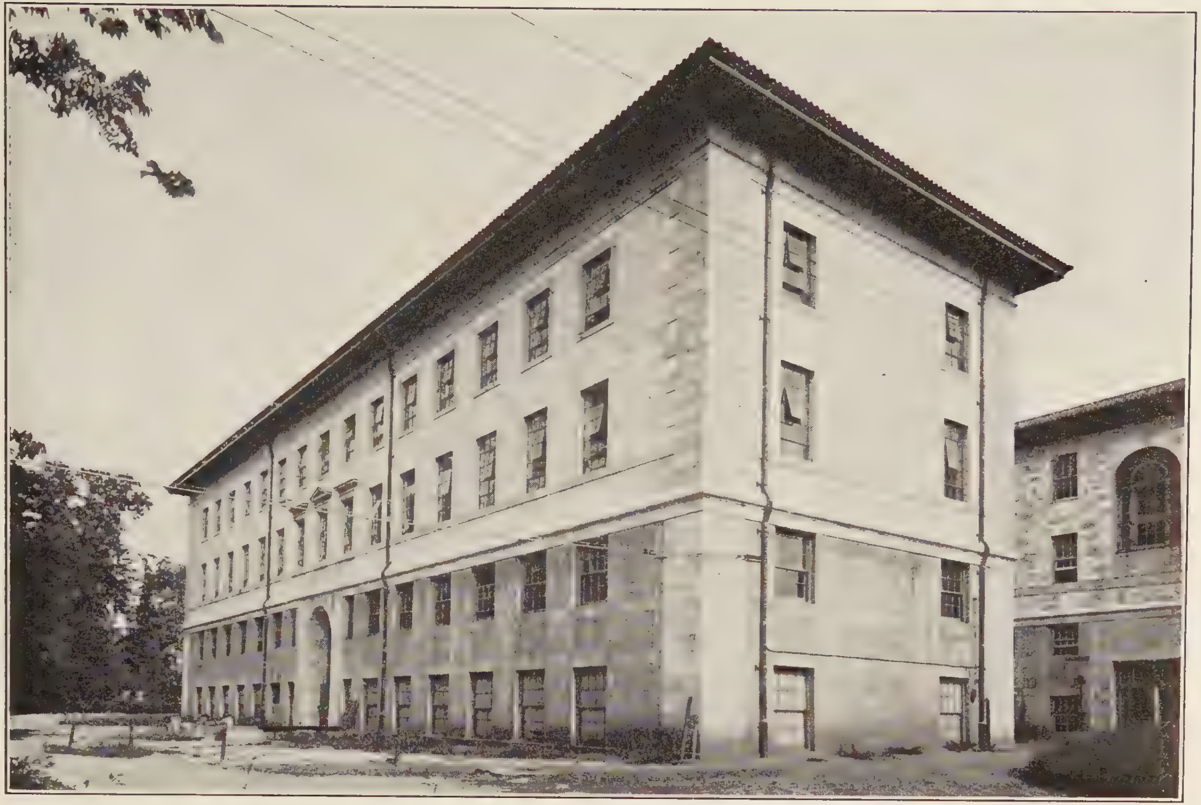

Figure 4.—Chemistry Building, Emory University, Georgia. Erected 1925

even more. It is very clear that this budget allowance should not be less than $10.00 per student. Ten institutions reported no laboratory fees charged. This seems to be a poor policy since institutional funds cannot usually be relied upon for an adequate budget.

It was surprising to find also that in thirteen institutions the student laboratory fees exceeded the budget allowance to the department (exclusive of payroll). This it is believed should never be allowed. The laboratory always needs these fees and they are collected primarily for laboratory expenses.

Technical Libraries for Chemistry

Facilities for the teaching of chemistry at the larger institutions visited were on the whole fairly satisfactory as regards buildings and equipment. The great need was for better working libraries in chemistry. Their development is of the very greatest importance and much attention was given to a study of the library situation. The facts gathered are summarized in the following article. In addition to the facts detailed in that chapter, Part V lists all technical libraries of importance in the South concerning which it was possible to obtain the desired information, and gives the periodicals and back sets available in each library. For this purpose the *Chemical Abstracts* list of 1500 periodicals was used as a guide.

Good technical libraries lie at the very foundation of future progress in chemistry. Some excellent technical libraries exist in the South and some of the institutions at which the technical library facilities are now inadequate are rapidly improving the value of their libraries for technical reference work. In many places it is, however, not possible to consider the present library facilities adequate and no sufficient attempt is being made to have the libraries serve the rapidly increasing demand which will come from educational and industrial expansion. There is no need to hamper educational progress and industrial prosperity in the South by failing to have available the information gained by thousands of individuals and laboratories.

Technical reference libraries are expensive. But it is a hundred times more expensive to repeat in the laboratory work already done. An industry that fails to make use of existing knowledge definitely limits its growth and perhaps its life.

Every chemist in the South, and every industrial organization in the South using a knowledge of chemistry in its operations, should become actively interested in building up the technical reference libraries in the South. The industrial organizations will receive a two-fold benefit from such effort. Better library facilities will become available to their technical staff, and the technical men, who in the future enter their employ, will be better trained.

Teaching Schedules

At many places teachers in chemistry are overloaded with teaching hours, permitting little time for research work. This is due in part to the rapid growth of the institutions and to the increased interest in chemistry, the budget having failed to advance correspondingly. This difficulty is, however, aggravated at nearly all institutions by the ruling of the Association of Colleges and Secondary Schools of the Southern States that "Teaching schedules exceeding sixteen hours per week per instructor shall be interpreted as endangering educational efficiency. In general, two laboratory hours will be counted as equivalent to one recitation hour."

The result of this ruling is that many teachers in the chemical departments carry from twenty to twenty-five clock hours of classroom and laboratory work per week. Some few teachers carry thirty hours and fourteen institutions out of eighty-eight reported that in some cases in their institutions more than two hours of laboratory work were counted the equivalent of one hour of teaching. So much interest was expressed in this subject that a separate chapter (IV) has been devoted to its further discussion.

Teaching of Chemistry in the High Schools

In almost all southern states the complaint was heard that students specializing in chemistry were not allowed to teach chemistry in the high schools of the state. This situation arose because the large number of hours required of the student for educational and other courses did not permit sufficient time for specialization. However laudable the aim of such requirements at the present time, the result is that the teachers of chemistry in the high schools are markedly deficient in their knowledge of chemistry.

In response to a general interest in this situation and to some requests for detailed information with regard to the facts Chapter III was prepared.

Degrees

Only six of the institutions listed now seem really to grant the degree of Doctor of Philosophy or Doctor of Science for work in chemistry. In general, sufficient care seems also to be exercised in granting the degree of Master of Arts and Master of Science. In some places the courses in chemical engineering need strengthening.

It is quite evident, however, that many of the smaller and poorly equipped institutions grant a special Bachelor of Arts or Bachelor of Science degree to students specializing in chemistry when the work required could hardly be sufficient to include much specialization. Some authoritative statement with regard to the granting of this degree might be desirable.

37-21

Fellows and Assistants

Sixty-five fellowships were reported with an average value of $642 and one hundred thirty-four graduate student assistants are employed at an average salary of $576.

Many students from the South receive fellowships or assistantships at the larger universities in the North and Middle West. This opening for graduate chemical students of the South is certainly not to be discouraged. At the same time it must be remembered that many of these students never return to the South, and also it increases the difficulty of building up graduate schools in the South. Some institutions, as for instance Rice Institute, could train well more graduate students than remain at the institution.

It must be recognized therefore that until more fellowships are available for graduate students the building up of graduate schools in chemistry in the South will be a very slow process.

It is, however, very important that strong graduate schools in chemistry be built up at those institutions which can afford to take the leadership. The six institutions now granting the degree of Doctor of Philosophy or Doctor of Science in Chemistry will be doing a real service to the South by using every effort to extend this work. These institutions are the Universities of Virginia, North Carolina, and Texas, Duke University, Rice Institute, and Vanderbilt University.

Research Work

Thirty-one of the larger institutions, including the medical schools and some of the experiment stations, reported three hundred seventy-six researches of a more or less chemical nature in progress. There is a great deal more chemical research work being done in the South than is generally realized. On the other hand, forty-six of the smaller institutions reported only thirty-one researches in progress. Of a total of eighty-eight institutions reporting, no chemical research was being done at thirty-five.

Before all of the data had been collected the writer undertook to arrange in order the sixteen institutions in the South leading in research work and research spirit. This list cannot be given here because there was no way to free such a list from personal judgment and error. It may be stated, however, that this list was compared with the then existing list of chemical library facilities. Thirteen of the sixteen names heading the library list were on the research list chosen, which can be considered only as additional evidence of a fact already well known—not very much successful research work in chemistry can be done without library facilities.

In addition to those institutions which are leading in research work there are others paying a considerable amount of attention to research, though

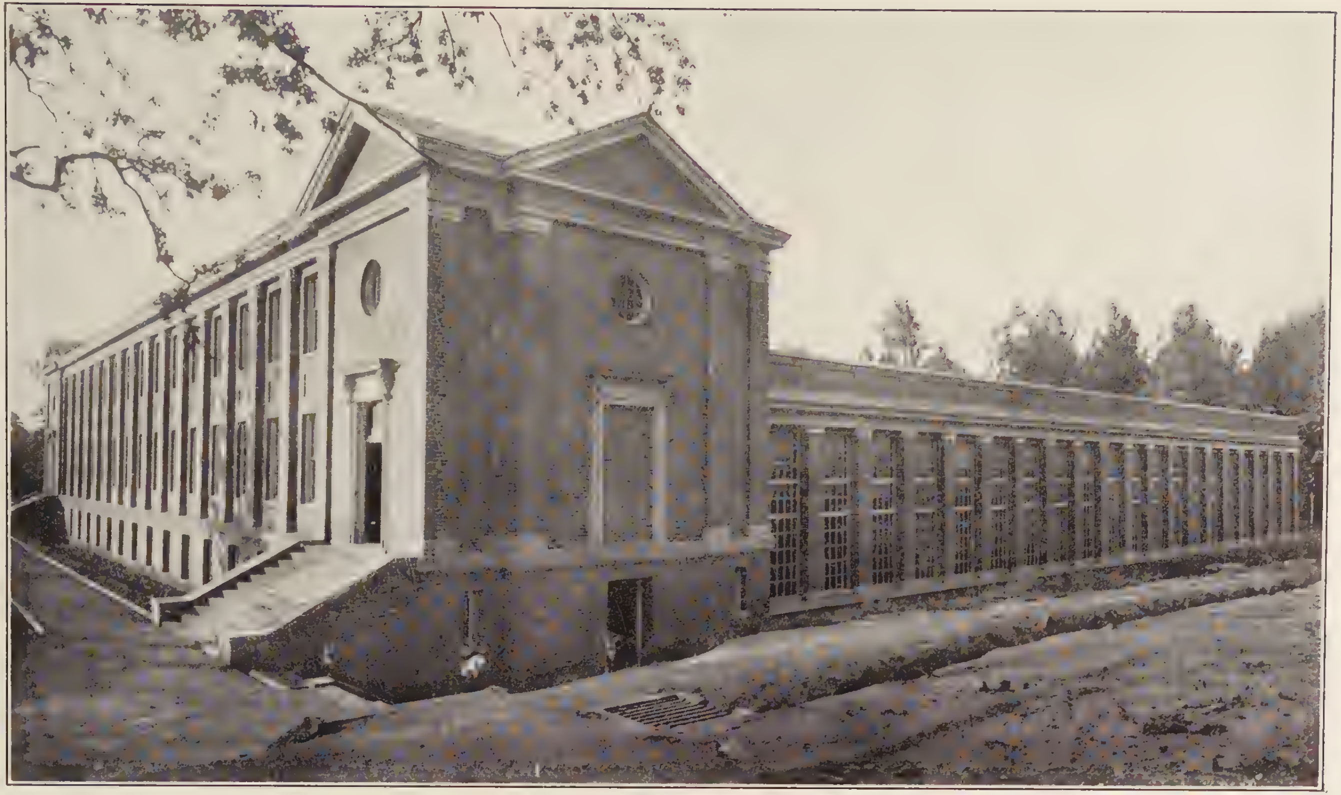

Figure 5.—Venable Hall, University of North Carolina, Chapel Hill, N. C. Erected 1925

lack of enthusiasm or encouragement, lack of buildings or equipment, and lack of library facilities handicap the effort made.

That it is possible to do research at a small, poorly equipped institution is shown by the record of Howard College, at Birmingham, Alabama, but such examples are hard to find.

In determining the amount of research work done, the influence of the president of the institution and of the head of the department of chemistry is so paramount as to enable the influence of these two men to be considered as of almost determinative character. If both of these men are in favor of research work, difficulties are overcome and some work is done regardless of handicaps.

The great need for research work on some of the industrial problems of the South is discussed in other articles of this series. Cannot the South definitely organize, through coöperation, its research work on some of these problems in such a way as to secure their early solution?

Too many men feel diffident about undertaking work on a big problem. Therefore, they finally choose some problem of little importance. If the work does not meet with considerable success they lose interest and cease all research work. Coöperative work on a big problem would tend to overcome this difficulty.

A general once gave to his officers this advice—"Never undervalue yourself in action. Never overvalue yourself in a report." Courage is as necessary in research work as on a battlefield. If the worst comes to the worst, die trying!

Smaller Accredited Colleges

Perhaps one of the most important results of this study lies in the possibility of being able to draw a fairly accurate average picture of the conditions as regards the chemical department which exist in the smaller accredited colleges, amounting probably to sixty per cent of the total number of colleges and universities accredited.

Excluding the thirty-three institutions listed in Table III and the medical schools, replies were received from forty-seven institutions. Of these institutions five reported the total number of students in all courses in chemistry as between three hundred fifty and four hundred fifty. The remaining forty-two institutions reported the total number of students in all courses in chemistry in every case as less than two hundred fifty and the average number of students in chemistry in these institutions as given is one hundred five. These forty-two institutions are taken as representative of the smaller accredited colleges.

The average payroll in such institutions for the chemical department is $5035 and the average budget is $1655. The average payroll, per student, is $45.80 and the average budget, per student, is $15.80. Comparing these figures with the larger institutions where the number of students enrolled in the various courses in chemistry is around eight hundred thirty-eight, the average payroll, per student, is $38.50, and the average budget, per student, is about $13.20. Thus, in spite of the increased advantages for technical training in chemistry offered by the larger institutions, the cost to the institution, without considering interest and depreciation in either case, is about $10.00 less, per student, for the larger institutions.

The budget is nearly covered by the fees charged the students, which amount on the average in the smaller institutions which charge laboratory fees, to $12.40 per student course.

In these small institutions, the average value of the non-permanent equipment, per institution, is $7424, and per student is $71.50.

Of the fifteen hundred periodicals abstracted by *Chemical Abstracts*, forty-five institutions reported an average number of seven periodicals received. Only rarely did the institution have complete back sets of any of the periodicals. The average number of volumes devoted to chemistry exclusive of periodicals and Government publications was estimated at two hundred sixty-two per institution. The total value of the chemical library will probably be under $1000.

In these smaller institutions many of the instructors teach from twenty to twenty-five clock hours and a few teach thirty. In the majority of these institutions no research work in chemistry is attempted. Often, however, some one in the chemical department is carrying out some investigation, which probably in time will result in a creditable contribution.

Women's Colleges

The only state-supported colleges for women, as separate organizations, in America, are located in the southern states as follows (*3*):

	Year founded
Mississippi State College for Women, Columbus	1884
Winthrop College, Rock Hill, South Carolina	1886
Georgia State College for Women, Milledgeville	1889
North Carolina State College, Greensboro	1893
Alabama College, Montevallo, Alabama	1896
College of Industrial Arts, Denton, Texas	1903
Florida State College, Tallahassee	1905
Oklahoma College for Women, Chickasha	1909

As far as the writer has been able to ascertain no woman's college in the South seriously considers offering training in chemistry as a profession for women. The women who choose this career must go to co-educational institutions or to women's colleges in other parts of the country. Perhaps this is best.

Local Sections of the American Chemical Society

One or more local sections of the American Chemical Society exist in all of the southern states except Mississippi and Arkansas.

There would seem to be abundant opportunity for the local sections as organizations to work for the progress of chemistry in their localities:

Aid in building up the technical chemical libraries.
Work for the improvement of the teaching of chemistry in the secondary schools.
Encourage research work and research workers.
Take an active interest in furthering chemical industry.
Promote good fellowship and coöperative effort.

The Virginia Section is setting an example which other local sections might follow to advantage.

Gifts to Departments of Chemistry

The total value of all gifts of money to the chemical departments of the 88 institutions from which replies have been received, exclusive of institutional funds, fellowships, and certain funds for special researches, have amounted *during the last ten years* to less than $105,000. Of this sum about $45,000 was contributed to the chemical libraries. Probably $35,000 is now being contributed annually for special researches. In addition, sixty-five fellowships amounting to a total of $41,730 annually are reported. One institution, Millsaps College, reported that its science building was from funds contributed for this particular purpose.

The detailed information upon which the above statements are based is interesting and is given below:

	Chemical department	*Chemical library*	*Chemical research annually*
Duke University		200	28,000
University of Georgia	15,100	10,500	
A. & M. College of Texas	16,000		
University of Virginia		15,000	
Rollins College	8,000		
Wesleyan College	6,000		
University of North Carolina		6,000	
Vanderbilt University		5,000	
Emory University	5,000		
Medical College of Virginia			4,000
University of Florida		2,000	1,100
University of Richmond	1,200	1,600	
University of Louisville	1,800		
University of Alabama	1,000	500	
University of Oklahoma	1,000	500	
Southwestern University	1,000	300	
Virginia Polytechnic Institute	1,200		

	Chemical department	*Chemical library*	*Chemical research annually*
University of Tennessee		1,000	
Washington and Lee University		1,000	
University of the South	500		
Under $500 total	475	590	
	$58,275	$44,190	$33,100
65 Fellowships			$41,730

It should be stated that except for the state-supported institutions all institutional funds are from gifts. Certain libraries have received gifts of books. Some of the special departments such as the textile schools, and the cottonseed school, have received valuable gifts of machinery.

It is very clear from the above statements that little outside aid has been given directly to the upbuilding of the chemical departments of the South. It is to be hoped that those profiting by chemical industries in the South will increase their interest in this matter.

Even after making due allowance for institutional gifts the situation seems rather pitiful. The powerful industries in the South mentioned in Part IV on STATISTICAL INFORMATION owe much of their success to chemistry. Both the industries themselves and the individuals who have profited from the operation of these industries in the South might well afford to give serious thought to the men, to the locality, and to the science that taken together have made the success of the industry possible.

Industrial Progress Assures Continued Growth of Chemical Departments

The industrial expansion in chemical and allied industries in the South has been very rapid and this expansion is continuing at the rate of tens of millions of invested capital each year. Some statistical information on these industries is given in Part IV. Table XXXI lists recent new industrial developments in chemistry in the South amounting to upwards of $120,000,000 and covers a period of about two years. The list is not complete. It may here be pointed out, that, in addition to the textile, cottonseed oil, fertilizer, petroleum, natural gas, iron and steel, cement and similar industries whose importance in the South is generally recognized, there is an increasing trend in other industries toward the South. There are now sixty paper mills and thirty-six pulp mills in eleven southern states, and thirteen glass factories in Oklahoma alone. Fifty per cent of all of the rayon manufactured in the United States is manufactured in the South. These and many other industries call not only for extensive supplies of raw materials but for many chemical products whose manufacture in the South will eventually follow. Natural gas lines are being extended from Louisiana as far as Atlanta. Enormous hydro-electric power is available and interlocking high-tension lines cover most of the industrial districts.

This industrial expansion calls for an ever-increasing number of chemists. Practically all institutions in the South stated that they could place all students trained in chemistry whom they could recommend.

It was found that paid connection with industry by members of the faculty of the chemical department was in general forbidden only in a few institutions, and generally those institutions were in states backward in chemical progress. When members of the chemical department are in close contact with industry the entire chemical department may often be enlivened and invigorated by such contact.

Many extremely important industrial chemical problems of special interest to the South await solution. The first great need of the South—*increased technical library facilities*—has been mentioned. A second great step toward further progress could be made by *coöperative organization to undertake the solution of certain particularly important industrial problems.*

Chemistry is a science to be used and chemical education that does not bear that fact continually in mind is a failure.

References

(*1*) Accredited Higher Institutions, *The Educational Record*, Apr., **1930.**

(*2*) Choice of a Medical School, Dec. 15, 1929, American Medical Association.

(*3*) Association of Colleges and Secondary Schools of the Southern States, **1929,** p. 284.

CHAPTER II

CHEMICAL LIBRARIES IN THE SOUTH

J. E Mills, National Research Council, Washington, D. C.

It is hard for the mind to grasp the amazing increase in the literature concerning chemistry that has taken place in the last thirty years. *Chemical Abstracts* now abstracts 1500 periodicals. It is becoming increasingly difficult to maintain effective contact with the advance in any given field. Private libraries for more than very specialized fields are no longer possible. The growth of public and institutional libraries has to be carefully planned, and in a given locality should be coöperative, in order to secure the most efficient results.

The Need for Increased Chemical Library Facilities

The growth of library facilities in chemistry throughout the South has not kept up with the advance made in laboratory buildings and equipment except in a few institutions. The establishment of more efficient working library centers in chemistry in the South is essential for the following reasons:

1. To promote research in chemistry.
2. To support the work necessary for graduate work in chemistry.
3. To supply the needs of industrial chemists in the locality.
4. Because additional research work must move South to accompany the southward movement of many chemical industries.
5. Because the advent of good roads has extended the area effectively served by a library center.
6. Because it is no longer possible for large library centers to loan back numbers of the most-used chemical periodicals.
7. "The lack of a supply of information as complete as the records will provide is bound to result in (1) the use of inferior apparatus and experimental methods, (2) poorly planned investigations and (3) useless duplication. *** The literature is really the very foundation of every scientific inquiry of importance." (Crane and Patterson: "The Literature of Chemistry.")
8. The library facilities will have a great deal to do with the future personnel of the chemical department. The best men do not generally continue to work at a place where the library facilities are poor.

The Present Status of Chemical Libraries in the South

The complete list of 1500 periodicals abstracted by *Chemical Abstracts* was sent to all of the accredited colleges and universities and medical

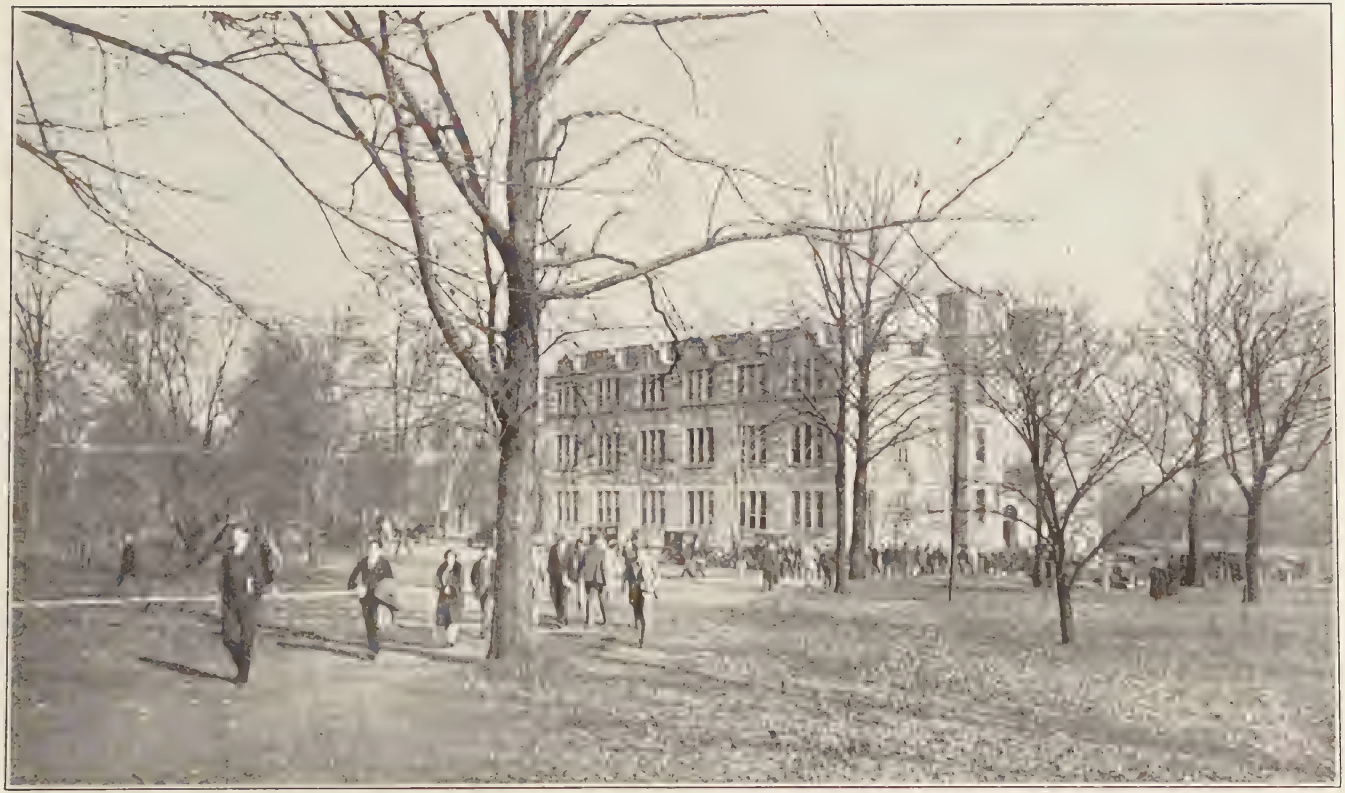

FIGURE 6.—FURMAN HALL, VANDERBILT UNIVERSITY, NASHVILLE, TENNESSEE. ERECTED 1906

schools, and to city and state libraries where a previous inquiry had shown that the technical library facilities in chemistry were worth listing, with the request that all current and back sets be listed. Excellent coöperation was obtained from nearly all institutions and libraries and the detailed information obtained when the library proved worth listing from a reference standpoint is given in Part V of this study.

The information obtained from the colleges and universities is summarized in Table I and from other libraries in Table II. Libraries which contained such a small amount of material relating to chemistry as to be of no importance as technical reference libraries were generally omitted. It should be noted that some institutions quite wisely adopt the policy of not building up their technical reference library facilities because such libraries are available to their students at other institutions. Thus H. Sophie Newcomb Memorial College has available the library facilities at Tulane University, and George Peabody College for Teachers has available the excellent library at Vanderbilt University.

Every effort was made to include all of the library facilities relating to chemistry at each institution listed, provided the entire institution was located in the same city. Thus the periodicals listed include those abstracted by *Chemical Abstracts* found in the main library or in the various departmental libraries, or in the library of the experiment station.

In Table I the libraries are arranged in order of the number of complete sets of periodicals listed by *Chemical Abstracts* at the institution named. Some uncertainty in interpretation may introduce occasional errors in the counting. This order of listing does not always arrange the libraries in the order of their importance as reference libraries in chemistry. An actual valuation of the library books and periodicals relating to chemistry at each institution would have given exactly comparative data as to the value of the libraries but this work could not be undertaken.

It should also be remembered in comparing the libraries at different institutions that the character and extent of the library is, and should be, determined by the work undertaken by the institution. Thus an agricultural college, experiment station, or a medical school must of necessity take many periodicals abstracted by *Chemical Abstracts* which may be of very little importance to an institution not directly concerned with work in agriculture or medicine.

A study of this table shows that most of the medical schools have access to fairly adequate libraries on the chemical side of medical literature. Important exceptions are the Wake Forest Medical School (two years), the Medical School of the University of Georgia at Augusta (four years), and Emory University School of Medicine (four years).

TABLE I

Library Facilities

			Relating to Chemistry				
			Periodicals[3]				
	Institution	*Volumes in library 1927*	*Current*	*Complete sets*	*Total*	*Books*	*Budget*
1	Duke University	163,000[2]	250	199	287	800	5100
2	University of Texas	430,082[1]	258	134	293	2388	1500
3	Vanderbilt University	98,000[1]	238	123	279	2284	750
4	Rice Institute	65,000[1]	232	110	240	1350	..
5	Univ. of North Carolina	210,511[1]	151	109	234	..	600
6	Univ. of Texas, Sch. of Med.	13,230	141	89	187	500	700
7	University of Alabama	75,000	111	76	111	200	1000
8	University of Tennessee	96,173	158	75	165	1000	1000
9	University of Arkansas	95,000[2]	163	73	167	1100	1000
10	University of Virginia	163,162[1]	178	68	240	1797	..
11	Medical College of Virginia	13,000[2]	139	68	142	..	..
12	University of Florida	58,000	162	58	175	1400	5000
13	University of Tenn. Med. C.	10,000[2]	118	55	145	213	..
14	University of Oklahoma	100,000	157	51	220	1155	1500
15	University of Kentucky	95,005[1]	200	50	247	770	650
16	Univ. of Okla. Med. School	3,485	95	46	113	..	1000
17	Virginia Polytechnic Institute	40,000	128	43	182	1150	250
18	University of Georgia	63,500	101	43	115	1000	..
19	Louisiana State University	90,000[2]	182	33	192	2000	700
20	Clemson College	24,398	121	31	132	654	250
21	University of Louisville	15,813	85	30	99	2000	500
22	Univ. of Arkansas, Sch. of Med.	8,242[2]	46	30	52	1966	..
23	Mississippi A. & M. College	49,719	85	29	85	2234	1200
24	Oklahoma A. & M. College	59,461[2]	161	24	187	1000	1250
25	North Carolina State College	23,886	121	22	153	..	..
26	Med. Coll. of State of S. C.	5,500	75	22	92	55	..
27	A. & M. of Texas	89,445	109	21	148	1000	485
28	Tulane University	134,390[1]	80	19	95	600	500
29	Georgia School of Tech.	25,000	52	19	57	..	..
30	Alabama Polytechnic Inst.	50,000	52	18	75	675	1215
31	Washington & Lee University	60,000	24	16	28	2900	500
32	College of William & Mary	50,000	48	10	59	230	150
33	Texas Christian University	38,500	22	8	24	180	200
34	University of South Carolina	105,000[1]	19	8	20	882	500
35	University of Mississippi	46,000	47	6	47	350	200
36	University of Richmond	45,000	15	6	19	625	200
37	Wake Forest College	36,100	6	6	7	500	200
38	Emory University	108,000	38	4	44	250	610
39	Univ. of Georgia, Med. Dept.	6,100	7	4	7	503	350
40	Baylor Univ. C. of Medicine	4,500	66	Incomplete		..	..

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[1] 1928–29.

[2] 1930.

[3] Included in *Chemical Abstracts* list.

Library Centers

Having regard to existing library facilities and to the geographical situation, it is believed that especially important library centers for technical information should be maintained at five points in the South:

University of North Carolina—Duke University (these institutions are only twelve miles apart).

Atlanta, by the coöperation of Emory University, Georgia School of Technology, and Carnegie Library of Atlanta.

New Orleans, by the coöperation of Tulane University and Howard Memorial Library.

Austin—University of Texas.

Nashville, by the coöperation of Vanderbilt University and The Carnegie Library of Nashville.

In addition, all institutions endeavoring to do a considerable amount of research work in chemistry or to give Master of Arts, Master of Science, or Chemical Engineering degrees should take not less than one hundred of the most important chemical journals for their work and should fill in the back sets of the same. This would probably necessitate a technical chemical library of a value of about $30,000 and an annual budget of at least $1000.

Another way of looking at the matter is that the technical chemical library facilities in each state should, by the coöperation of the various institutions and departments most concerned, be built up to the point where some three hundred of the journals and back sets listed by *Chemical Abstracts* are available somewhere in the State. This goal is attainable. Practically all knowledge of chemistry, as regards both its fundamental aspects and its practical applications, is contained in the literature of the subject and this must be available if progress is to be made and much useless and wasted effort avoided.

It is to be emphasized that the development of the libraries in each state should be coöperative up to the point where duplication can be afforded. Thus in South Carolina the Clemson College Chemical Library should emphasize agricultural, engineering, and textile chemistry; the Medical College of the State of South Carolina—physiological, pharmacological, and sanitary chemistry, and the chemistry of nutrition and hygiene; and the University of South Carolina Chemical Library should emphasize the standard and fundamental aspects of the science. By such a coöperative understanding the library facilities in the State could be increased more rapidly and effectively than the resources of any one of the institutions would allow. These institutions are sufficiently far apart to justify eventually a large duplication. At the present time the hard-surfaced roads which exist make the progress of any library in the state a matter of importance to workers in every part of the state.

Building Up a Chemical Library

All who have the responsibility for the building up of a chemical library will find the excellent work on "The Literature of Chemistry" by Crane and Patterson invaluable. See also a "List of Periodicals Abstracted by *Chemical Abstracts* with Key to Library Files," published by the American Chemical Society in part from data obtained by the Research Information Service of the National Research Council. A study of this list will show those periodicals relating to chemistry found most useful by the libraries of the United States.

A real library is not a lot of books which can be ordered by the yard or even by the set. It is more like a living, growing organism which gives pleasure and fills a definite need from day to day. Suggestions may do more harm than good unless modified for the particular situation which exists. But do not hesitate to build up the library also for the future. Sacrifice somewhat on chemicals and apparatus if that be necessary to insure its growth. It is difficult to persuade good men to continue to work where the library facilities are poor. Your library facilities will have a lot to do with the future personnel of the department and may have a great deal to do with the progress of chemical education and chemical industry in your vicinity.

The chemical library should particularly consider the needs of:

Educational institutions.
Experiment stations and those working on agricultural problems.
The related fields of medicine, pharmacy, sanitation, and hygiene.
Local chemical industries.
The non-technical public.

This means the procuring of:

Current technical, chemical, and related trade periodicals.
Back volumes of standard and most-used chemical periodicals.
Reference books and tables.
Government scientific publications.
Technical books.
Popular scientific books relating to chemistry.
Informational books.

In building up a chemical library it is not possible immediately to complete back sets of journals as desired without great expense. Watch out for bargains and gradually fill in by accepting the most advantageous offers. When it comes to journals like the *Philosophical Magazine, Philosophical Transactions, Liebig's Annalen, Annalen der Physik, Annales de Chimie,* and *Comptes Rendus*, forego the pleasure of filling in too far back unless you are sure that you can afford from your library budget these very valuable but expensive sets. Complete sets of the six journals mentioned are hard to obtain and prices are very variable. Perhaps, even if some reprints were accepted, these journals complete would be worth upward of $12,000. Most of the actual references obtained to these journals will be confined to the last thirty years. Obviously, unless money is quite plentiful, it is better to purchase these expensive journals only as far back as sets can be obtained at a reasonable valuation. Spend most of the library budget on journals covering the last thirty years. The first twenty or thirty volumes of the *Journal of the American Chemical Society* are now difficult to obtain and their cost is quite out of proportion to the cost of the later and more valuable volumes.

When the back sets are not too expensive make them complete. All the care and attention given to this work is doubly worthwhile because such purchases increase the immediate usefulness of the library and because in the future it will not be possible to obtain the missing volumes.

Government scientific publications are becoming increasingly valuable. Secure regularly those publications desirable and bind them. These Government publications can generally be obtained without cost.

Try to induce other departments related to chemistry to build up their libraries and thus make available the related journals of interest to chemists.

Seriously interest chemists and chemical industries in the locality in building up the library for their use. The real value of the library to the institution and to the community does not depend on the value of the periodicals and books which it contains but on the use which is made of them.

Management of the Chemical Library

The library should be in a fireproof building. If that question can be satisfactorily settled all remaining questions can be answered as corollaries following from the statement that *the prime object of the library is to render the greatest possible service to all desiring its use.* If, therefore, at a particular university a chemical department, an experiment station, and a physiological department, each housed in separate buildings, all have frequent call for the chemical library, divide the library into three parts, giving to each organization the journals and books with which it is most concerned (provided again the buildings are fireproof). Let no one persuade you that under the above circumstances the library should be placed in the main library for the use of all but convenient to none.

The departmental library should be considered a part of the main library and so cataloged, but it should be placed where it can be of the greatest possible service. If divided each organization should have a card catalog of the whole.

It is certainly not always necessary to have a full-time departmental librarian. A little care in instilling a "right spirit" will generally insure against all but trivial loss. Library service is of advantage if not too costly, but do not let it interfere with a certain freedom in "browsing around" most valuable to students seriously desirous of learning something of chemistry. There are no more valuable hours in the entire course than those spent by the student in getting acquainted at first hand with the literature of the science he expects to follow.

Make the library as useful as possible to the locality. If an institution has a good library let that fact be known to all chemists in the locality and invite its use freely and with only absolutely necessary restrictions. Moreover, arrange to give the greatest possible amount of library service to those less fortunately situated. Some seed will fall on good ground and bring forth fruit.

Keep up with the binding of back numbers of journals. Failure to do so is a source of constant annoyance and is certain to result in the almost tragic loss of some number which cannot be readily replaced.

No matter how good the library, it will sometimes not prove sufficient. Have the main librarian arrange with some large library to obtain co-operation in filling the various needs which arise. Make use of occasional loans, of photostats, and of the fact that some advanced students at large institutions are working their way through college and are quite glad to "look up the literature" for a stated sum per hour of work.

The office of *Chemical Abstracts* will lend rare chemical periodicals not available elsewhere, a charge of twenty-five cents for use during forty-eight hours being made. This service is not available for journals that can be obtained through the usual channels.

Smaller Institutions

The smaller educational institutions cannot hope to build up reference libraries in chemistry and should make no attempt to do so. But it was rather pitiful to find that forty-five of these smaller accredited institutions received an average of only seven of the fifteen hundred periodicals abstracted by *Chemical Abstracts*. It should be remembered that *Chemical Abstracts* abstracts such journals as *Science* and the *Scientific Monthly*. Only rarely did the institution have complete back sets of any of the periodicals. The thirty-two similar smaller institutions that made no report would, it seems certain, show no better average, because on the whole the reports came from the stronger institutions.

The average number of volumes devoted to chemistry, exclusive of periodicals and Government publications, was estimated at 262 per institution. The total average value of the chemical library of these institutions would probably be under $1000. The average budget reported for the library in chemistry was $148.

The chemical library of these smaller institutions should contain:

Popular scientific books relating to chemistry.
Technical books.
Reference books and tables.
Probably as many as 30 well-chosen scientific periodicals relating to chemistry and closely allied subjects.

A better method of stating what should reasonably be expected of such institutions would be to state that the annual budget for the chemical library should never be less than $1.00 per student per course in chemistry, and the minimum budget should be $250.

Many chemists throw away the back numbers of journals to which they subscribe. Could not these journals be placed where they would prove of permanent value?

Public Libraries

Fifteen public libraries in the South were found to subscribe to from 13 to 146 of the periodicals listed by *Chemical Abstracts*. Back sets were usually non-existent or incomplete. As a rule most of the periodicals listed were trade journals. Information concerning these libraries is given in Table II, and the libraries are listed in Part V where the detailed information concerning them is given.

TABLE II

Public Libraries

		Periodical abstract list		
	Volumes in library	*Current*	*Complete sets*	*Total*
1 Birmingham Public Library	173,433	146	18	176
2 Houston Public Library	126,030	67	8	76
3 Louisville Free Public Library	324,424	60	6	100
4 Carnegie Public Library, Fort Worth	85,538[2]	60	6	60
5 El Paso Public Library	35,385	57	11	69
6 Tulsa Public Library	82,000	50	10	59
7 Carnegie Library of Atlanta	152,734	47	7	46
8 Goodwyn Institute, Memphis	21,516	41	6	43
9 Memphis Cossit Library	180,788	39	17	39
10 The Carnegie Library of Nashville	138,642	22	7	23
11 Richmond Public Library	77,060	19	1	22
12 Rosenberg Library, Galveston	82,000	18	5	40
13 Chattanooga Public Library	116,994	17	0	17
14 Howard Memorial Library	64,632[1]	15	3	25
15 Virginia State Library	220,000	13	0	13

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[1] In addition this library contains a large number of volumes not cataloged.

[2] This library contains also 28,623 pamphlets.

The Birmingham Public Library is greatly in advance of any of the other city libraries in the service rendered to chemists. This library deserves a great deal of credit for undertaking to supply the needs of the technical men in its locality, for neither Howard College nor Birmingham-Southern is in a position at the present time to build up reference libraries.

In Atlanta, Howard Memorial Library, Emory University, and the Georgia School of Technology should coöperate in building up first-class technical library facilities.

In Memphis, the Memphis Cossit Library, the Goodwyn Institute, The University of Tennessee Medical School, and Southwestern College could by coöperation speedily build up really excellent library facilities.

In Richmond, the Richmond Public Library, the Virginia State Library, the Medical College of Virginia, and the University of Richmond, by coöperation, could very rapidly make available excellent library facilities.

It is not necessary to continue such illustrations.

All city and institutional libraries should take care to complete back sets of the periodicals found most useful when these can be obtained at reasonable expense. Any periodicals abstracted by *Chemical Abstracts* that are worth taking are worth binding and maintaining as complete files.

The local sections of the American Chemical Society can do no more worthwhile work than that of aiding constantly in building up the reference technical libraries in their respective localities. It is probable that in most localities men could be found who would take a real pleasure in giving substantial aid to such a worthy objective. The librarians of representative city libraries will be glad to coöperate with the chemists of the locality in increasing the usefulness of the library to technical men.

Gifts for Chemical Libraries

The total gifts, exclusive of institutional funds and books, *during the last ten years*, to the chemical libraries of the eighty-eight accredited institutions in the South who have replied to the questionnaire forwarded, have been less than $45,000. These gifts are listed in the preceding chapter. One needs to view this small sum in the light of the statistics given of the various chemical industries in Part IV. Even the hard-headed business man will admit that it is not fair.

Moreover, if, as the writer believes, the building up of the technical chemical libraries in the South is the greatest need in securing additional progress in chemistry in the South, no one will benefit more in the long run from these increased library facilities than these same chemical industries.

Other Library Facilities

This study has been confined only to library facilities pertaining to chemical and related technical information. It would, however, be quite unfair not to point out the numerous and substantial gifts which have been made within recent years to city, college, and university libraries at many places throughout the South. Carnegie libraries are frequently found both in small towns of only a few thousand inhabitants and in the larger cities. Many other libraries and library buildings both in cities and at educational institutions are the result of gifts made directly for that purpose. Frequently the best building on a campus is the library building.

In 1929 the Julius Rosenwald Fund set aside $500,000 for county library development in the southern states. Each county aided must match the Rosenwald grant with local appropriations, and must present a well-considered plan to provide service to all parts of the county and all elements of the population, with separate extension agencies for negroes.

Some states have established state library extension agencies. In North Carolina the Citizens' Library Movement has given impetus to library development. The Virginia Federation of Women's Clubs made the establishment of county libraries their principal aim during 1929. To adequately recount the many individuals and agencies whose contributions and work have aided in library development in the South would not be possible here.

It is with the fullest appreciation of the tremendous importance and enduring usefulness of the work now going forward that attention in this chapter has been focused upon the need of increased technical library facilities for those who themselves advance scientific knowledge and who are often responsible for industrial progress.

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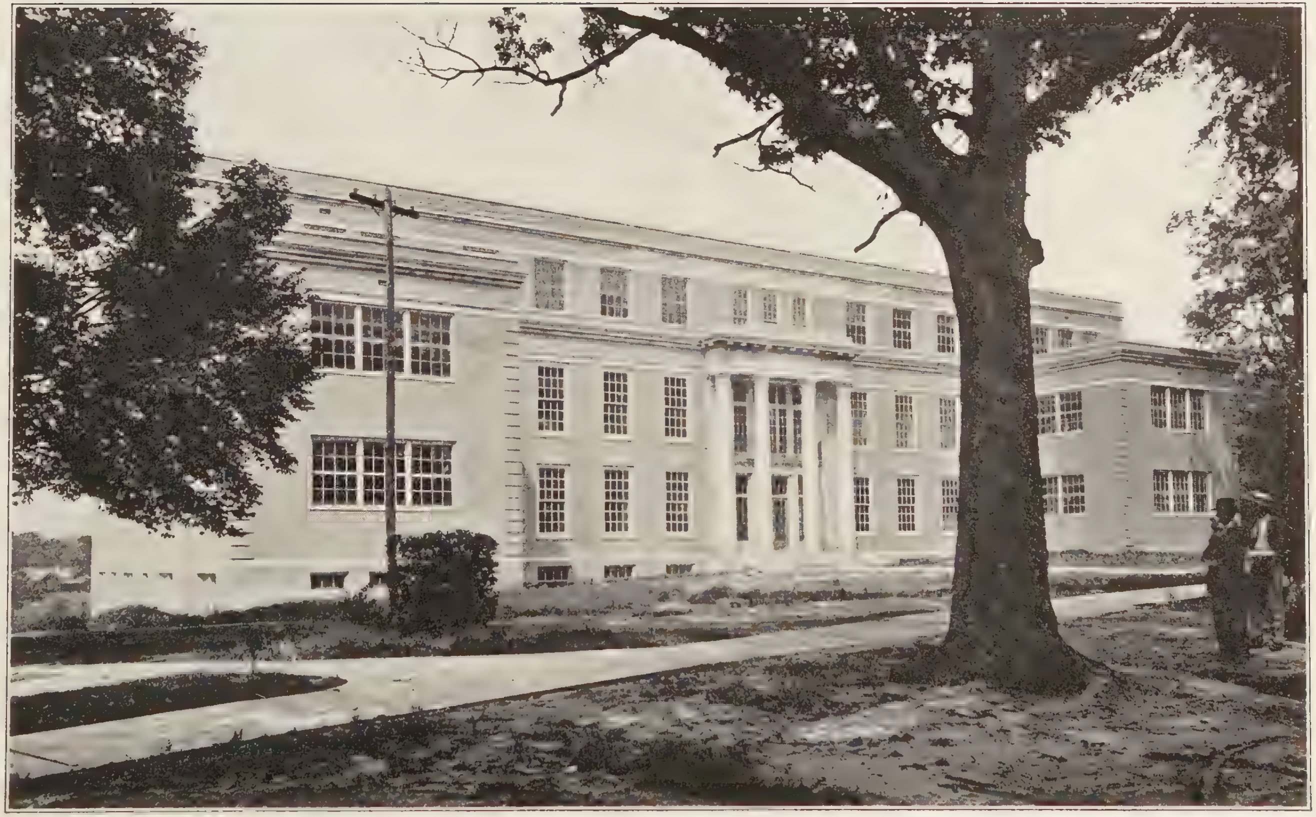

Figure 7.—Chemical Laboratory, University of Mississippi, University, Mississippi. Erected 1921

CHAPTER III

EDUCATIONAL REQUIREMENTS FOR TEACHERS OF CHEMISTRY IN SECONDARY SCHOOLS

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Practically no one in the entire country is ignorant of the tremendous increase in efficiency of the school facilities in almost every state in the Union in the last twenty years. No part of this progress is more striking than that made by the high schools. One important factor in securing this progress has been the adoption of standards for accredited secondary schools. These standards have been carefully adjusted and gradually raised to secure a continued growth both in material equipment and in teaching efficiency.

Although the science courses given in the high schools are necessarily of an elementary nature, it is important that such courses be well taught, since they constitute for students who do not later attend a college or university their entire fundamental training in science. For those students who later continue their studies the introductory course to a science may often prove of determinative influence in guiding all future work.

While, therefore, this study did not contemplate any examination into the conditions surrounding the teaching of chemistry in the high schools of the South, it was found that this question was so important and of such general interest that some consideration of the question could not well be avoided.

It was repeatedly pointed out that the high-school teachers of chemistry were often inadequately prepared to teach that subject. It was common knowledge that in general the training of high-school teachers in chemistry did not equal the training expected of junior chemists in the Government service, or the training expected of those entering a commercial laboratory.

Much more surprising was the fact that at the present time in some states a student who has satisfactorily specialized in chemistry at his state university, following exactly the course recommended by the institution, and who has received the degree of Bachelor of Science in chemistry, is not allowed to teach chemistry in any accredited high school in his state. In fact, very few of the teachers of chemistry in the accredited universities and colleges of the country could qualify to teach chemistry in the accredited high schools of many states. On the other hand, teachers possessing only the most elementary knowledge of chemistry are allowed to teach chemistry in the high schools of many states provided the teacher has taken certain specified educational work.

The facts stated above would indicate that somewhere an error in adjustment has been made which should receive careful attention. The question was therefore studied with the idea of presenting those facts which might aid in securing a better adjustment of conditions in the states concerned.

The standards of "minimum scholastic attainment" required of secondary-school faculties by the various accrediting associations are given below (*1*):

Association of Colleges and Secondary Schools of the Southern States

(*b*) The minimum scholastic attainment required of the faculty of any accredited secondary school on the southern list is that not less than 75 per cent of the total number of teachers of academic subjects, including the principal and teachers of agriculture and home economics, shall hold bachelor's degrees from a college approved by the association. Beginning with the school year 1927–28, all beginning teachers and principals shall have had not less than 12 semester hours' work in education.

North Central Association of Colleges and Secondary Schools

Standard 7.—All schools accredited by the association shall maintain the following standards respecting teachers:

(*a*) The minimum attainments of a teacher of any academic subject and of the supervisors of teachers of such subjects, shall be equivalent to graduation from a college belonging to the North Central Association of Colleges and Secondary Schools. Such requirements shall not be construed as retroactive.

(*b*) The minimum professional training of a teacher of any academic subject and the supervisors of teachers of such subjects shall be 15 semester hours in education. This requirement shall not be construed as retroactive.

The association recommends the following types of courses as meeting the spirit of this standard: Educational psychology, principles of secondary education, theory of teaching, special methods in subject taught, observation and practice of teaching, history of education, educational sociology, and school administration and supervision.

Northwest Association of Secondary and Higher Schools

Standard 7.—Preparation of teachers.—All teachers of one or more academic subjects must satisfy the following requirements:

(*a*) Graduation (bachelor or equivalent degree) from a college or university approved by the Northwest Association of Colleges and Secondary Schools, by a similar accrediting association, or by the educational authorities of the State in which the college is located.

(*b*) The minimum professional training of teachers of any academic subject shall be at least 12 (15 hours after September, 1927) semester hours in education. This should include special study of the subject matter and pedagogy of the subject to be taught. Such requirements shall not be construed as retroactive. (For the succeeding year the commission will interpret courses in education as the same courses are interpreted by the colleges or universities offering them.)

These requirements apply to no teacher already employed in a Northwest Association high school so long as the teacher remains in the same city system.

All academic teachers new to a school in any given year are required to conform to the standard. In case of violation the school will be warned and will be dropped the following year unless correction is made.

A school applying for the first time may be accredited if at least 80 per cent of the teachers of academic subjects fully meet the standard; the remaining 20 per cent must all have been employed in the school not fewer than two years immediately preceding the time of application.

The term "academic subjects" includes work of the following departments: English, laboratory science, mathematics, foreign language, history, and social science.

Association of Colleges and Secondary Schools of the Middle States and Maryland

Standard 4. The standard of preparation for a teacher of academic subjects shall be the completion of a 4-year course in a college approved by the association or in a college of equal rank. Due consideration shall be given to teachers with other than this preparation who have demonstrated their ability through successful experience, provided that at least three-fourths of the teachers of academic subjects meet the standards of preparation.

Teachers shall have had professional training or should have had successful teaching experience.

A school to be accredited shall have a salary schedule which is sufficient to secure teachers with the foregoing qualifications.

New England College Entrance Certificate Board

A school to be approved by the board must:

(1) Give satisfactory evidence as to curriculum, staff of teachers, and equipment.

(2) Be able to prepare for college according to some one of the recognized plans for entering a college represented on the board.

The accrediting associations mentioned above do not themselves grant Teachers' Certificates. These certificates are usually issued by the State. When issued by the County, the rules and regulations governing their issue are usually prescribed by the State. In each state different classes of certificates are issued and the state regulations regarding the same are not uniform *(2)*. The State laws often require more professional (educational) training than is required by the accrediting association in the territory concerned. This study is not concerned with the requirements for principals, superintendents, and supervisors of schools, nor with the requirements for elementary, kindergarten, or special teachers. The study is concerned only with the effect of certain regulations as they concern high-school teachers of chemistry.

The accrediting associations are not state controlled but their standards very properly have a large determinative influence, both upon the selection of teachers for high schools and upon the determination of state educational policy which finally becomes translated into law.

It is hardly necessary to point out that when a state has granted a certificate it by no means follows that an appointment as a teacher can be secured. Since the best high schools desire to be accredited by the association operating in the locality concerned, the regulations of the association are decisive when it comes to securing an appointment in an accredited school.

The American Council on Education for all practical purposes defined (*3*) a semester hour when it recommended that "A college should require for graduation the completion of a minimum quantitative requirement of 120 semester hours of credit (or the equivalent in term hours, quarter hours, points, majors, or courses) with further scholastic qualitative requirements adopted by each institution to its condition." This recommendation has been practically universally adopted. Measured then by this basis, 12 semester hours of work in education means 10 per cent of the total work required for graduation during four years of college life.

Every one at all familiar with college requirements understands how very sparingly college hours must be spread in order to cover even that degree of education commonly embraced in the Bachelor of Arts or Bachelor of Science degree. To illustrate we may suppose that the student desires to pursue a course without particular specialization in any science. The 120 semester hours are equivalent to 15 hours of credit work per week carried throughout each of the four collegiate years, a total of 60 college hours. Adopting as a unit one course meeting five times a week, we would have as a possibility:

	Non-specialized scientific course		*Course leading to B.S. in chemistry*
	Courses	*Hours*	
English	2	10	8
Mathematics	2	10	8
Physics and Elect. Engr.	1	5	5
Chemistry	1	5	24
Geology and Mineralogy	1	5	3
Botany and Zoölogy	1	5	0
German	1	5	3
French	1	5	3
Electives	2	10	6
		60	60

Both electives may and probably will be put on that science in which the student is more particularly interested.

If the student wishes to specialize in chemistry, it is generally desired that the student take, after the course in general chemistry, one course in each of the main subdivisions of chemistry and the allotment of hours (on the basis of 60 hours for a degree) to this subject will be somewhat as follows:

General Chemistry	5
Analytical Chemistry (Qualitative and Quantitative)	8
Organic Chemistry	4
Physical Chemistry	4
Industrial Chemistry	3
	24

The student should then have a good elementary grasp of his subject and the requisite number of hours required for this specialization is secured by arranging the hours in other subjects as shown above under the heading "Course leading to B.S. in chemistry." In practice the value of the units is shifted somewhat to accord with the college schedule as regards semesters, class hours per week and credits.

To prevent misunderstanding it may be stated that there is general agreement that at least six hours of electives should be allowed to the student. Also, it is in general impossible to cut down on the time allowed for English and mathematics. Physics as scheduled includes all that the student is to learn about electricity and its ordinary applications, and this requirement has been reduced to a minimum. The student of chemistry is so often concerned with problems connected with mineralogy and geology that the elimination of this requirement would seem unwise. The requirements for French and German can properly be eliminated for students who are to make chemistry their life-work only by making these languages entrance requirements. This is sometimes done, but the present status of high-school work in these languages does not in general permit of this solution.

Twelve semester hours for educational work are therefore approximately 25 per cent of the total time that could otherwise be devoted under the most careful arrangement to the entire study of the subject in which the student has made every sacrifice possible (in other college subjects) in order to specialize. In other words, a requirement of 12 semester hours for educational work ordinarily will mean that a Bachelor of Science student spends only 18 college hours in studying a science such as chemistry and six college hours in studying how to best use his knowledge in teaching. The requirement of certain states of 18 semester hours of educational work for a high-school certificate means that the student preparing to teach chemistry in the high schools spends during his college course probably 15 hours studying chemistry and 9 hours learning how to teach. If the teacher divides his time between two or more high-school subjects his preparation in any one of the subjects taught ordinarily becomes of necessity much less.

The State of Tennessee requires (*2*) for a permanent professional certificate valid in a high school, to teach subjects indicated by the certificate:

> Scholarship: Graduation from the University of Tennessee or a state teachers college or state normal school of senior grade or other approved college or university, with completion of at least 27 quarter hours in education as prescribed by State board of education; applicant must have a credit of not less than 18 quarter hours in special subject which he is licensed to teach.

Note that 27 quarter hours are required in education and only 18 quarter hours in the special subject which the teacher is licensed to teach. Such requirements are not unusual.

The question under discussion does not concern the South alone. A number of states require as high as 18 semester hours of work in education as a prerequisite to obtaining a certificate valid for teaching in a high school, and have no requirements as to the teacher's knowledge of the subject taught (*2*).

A committee of the Division of Chemical Education of the American Chemical Society reports (*4*) that 30 out of 44 states replying grant a blanket certificate which entitles the holder to teach any subject in the high schools of the state. Many of these states require a major and minor, or a major, but do not certify in that subject so that the teacher may teach any subject.

Hutson points out (*5*) that more than 30 per cent of 270 science teachers in the schools of Minnesota, from whom replies were received, had not received as much as 12 semester hours' training in any science.

Recently a study has been made (*6*) of the qualifications of 929 teachers in the high schools of South Carolina. Most of these teachers taught more than one subject. The following findings were based on the assumption that a teacher could be considered trained if he had taken 20 semester hours of college work in the subject taught.

Number prepared to teach subject taught	493
Number not prepared to teach subject taught	940
Number prepared to teach other subjects not taught	571
Number not prepared to teach anything	127

Those students who take a course leading to the degree of Bachelor of Science in chemistry in the leading institutions generally intend to enter industry immediately or after further specialization, or they intend after further study to become teachers in colleges or universities, or perhaps to enter some related science such as medicine. For these students it would not usually be desirable to substitute courses in educational work for courses in chemistry. It is not likely therefore that college requirements for the degree of Bachelor of Science in chemistry will become less specialized in that subject.

It is not denied that teachers or prospective teachers will receive benefit from educational courses. These educational courses embrace not only a study of teaching methods but deal broadly and in detail with school problems, curriculum and administration, with educational aim and policy, and those principles of general psychology applicable to educational method. But a knowledge of how to teach is not more important than a thorough knowledge of the subject matter to be taught. In general, that man will teach best who knows his subject best, and a few hours devoted to educational studies will not transform men, whose personalities unfit them for teaching, into good teachers. If it is essential that one receives instruction in how to teach a subject, as distinct from a knowledge of the subject itself, then there would have to be courses on how to teach the teaching of chemistry.

The result of the present requirements is that most of the teachers of chemistry in the high schools have far less knowledge of chemistry than is expected of junior chemists in the Government service or the new recruits in industrial laboratories. In other words, the high schools require of their teachers of chemistry less knowledge of the subject than is generally supposed to be necessary for its successful use in any other way. In fact the knowledge of chemistry required is so limited that the teacher often has not obtained a sufficient foundation for graduate work and usually cannot later make good his deficiency by post-graduate work that can at the same time be used as college credit for an advanced degree.

It is fully recognized that high schools cannot in general secure highly trained specialists to teach the various subjects taught. But it would seem desirable to frame standards for high-school teachers in a manner which would tend to encourage a thorough knowledge of the subject taught and which would permit of the degree of specialization desired by industrial laboratories of college and university graduates.

A United States Bureau of Education Bulletin (7) gives the results obtained from a study of 844 schools accredited by the Southern Association in 11 southern states for the year 1926–27. These schools enrolled 283,127 pupils and employed 11,807 teachers. Bachelor's degrees were held by 80.4 per cent of the teachers, Master's or Doctor's degrees by 11.2 per cent, and 8.4 per cent of the teachers held no degree. Some science course was being taken by 40.5 per cent of the total enrolment and chemistry by 7.7 per cent. More students were enrolled in some science course than in all of the following courses added together: home economics, French, manual training, art, agriculture, German, and Greek. It is important therefore that science be well taught.

A committee of the Division of Chemical Education suggests (*8*):

> Let every local section of the American Chemical Society plan at least one meeting a year which shall be of special concern to high-school teachers of chemistry—let it be chemical education night. The interest of these local sections in the chemistry departments of high schools in their respective areas would deepen the interest of teachers in their work and in turn the student body and the community.

Conclusions

A knowledge of how to teach is of little value unless accompanied by an adequate knowledge of the subject taught. Requirements for work in education should not therefore be pushed to the point where adequate specialization in the subject to be taught is prevented. It is suggested for the consideration of those concerned that a high-school teacher's certificate should be based on the following requirement:

> Graduation from an accredited college or university with not less than 40 semester hours' training in the subject or subjects taught.
>
> Professional training in educational work not to exceed 12 hours may be accepted as partial fulfilment for the required semester hours.

It is believed to be important that any requirement adopted should allow a certain amount of flexibility. Often the student does not know definitely the exact character of work that he will undertake upon graduation, or circumstances change a decision already made. The real object to be attained is to secure as high-school teachers those best equipped for the work desired. Some flexibility in the requirements demanded will prove of advantage.

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(*1*) "Accredited Secondary Schools in the United States," U. S. Bureau of Education, Bulletin No. **26** (1928).

(*2*) "State Laws and Regulations Governing Teachers' Certificates," U. S. Bureau of Education, Bulletin No. **19** (1927).

(*3*) "American Universities and Colleges," The American Council on Education, David Allan Robertson, Editor, **1928.**

(*4*) "How Are Teachers Being Trained in College for Teaching High-School Chemistry?" JOURNAL OF CHEMICAL EDUCATION, **5,** 743–7 (1928); **6,** 1156–7 (1929).

(*5*) P. W. HUTSON, *Educational Administration and Supervision,* **9,** 423–38 (1923).

(*6*) "A Study of South Carolina High-School Conditions," High School Division, State Department of Education, Columbia, S. C., **1930.**

(*7*) "Secondary Schools of the Southern Association," U. S. Bureau of Education, Bulletin No. **16** (1928).

(*8*) "The Professional Spirit among High-School Chemistry Teachers," JOURNAL OF CHEMICAL EDUCATION, **5,** 747–9 (1928); **6,** 1157–9 (1929).

(*9*) *Bulletin of the American Association of University Professors,* **15,** 558–62 (1929).

(*10*) J. O. FRANK, "Teaching First Year Chemistry," Fourth edition, J. O. Frank, Oshkosh, Wis., **1927.**

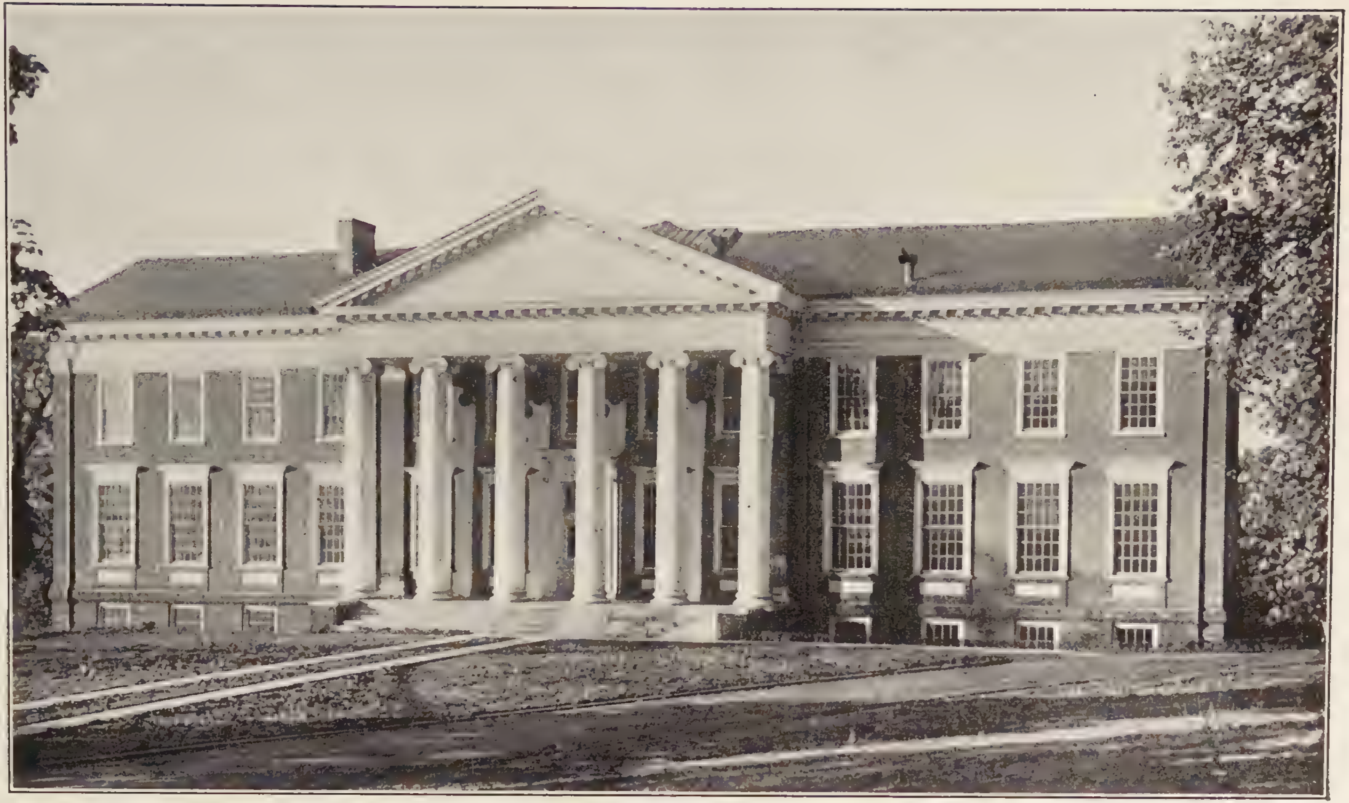

Figure 8.—Cobb Chemical Laboratory, University of Virginia, University, Virginia. Erected 1917. An Addition to This Building Is Planned

CHAPTER IV

TEACHING SCHEDULES IN THE CHEMICAL DEPARTMENT

J. E. MILLS, NATIONAL RESEARCH COUNCIL, WASHINGTON, D. C.

In visiting the chemical departments of many of the larger educational institutions in eleven southern states, the complaint of heavy teaching schedules was so frequently heard that the fact seemed to merit some special study.

It is not believed that any objection was raised to the standard in this regard as recommended by the American Council on Education (*1*). The suggested standard is the same for colleges, junior colleges, and normal schools and teachers' colleges, and reads as follows:

> Teaching schedules exceeding 16 hours per week per instructor, or classes (exclusive of lectures) of more than 30 students, should be interpreted as endangering educational efficiency.

The trouble lies primarily in the fact that some of the various accrediting associations have so worded their interpretation of this recommended standard as to lead to a general custom in certain parts of the country of considering two (or in some cases more) hours of laboratory instruction the equivalent of one hour of lecture.

The Association of American Universities in its "Memorandum of procedure for institutions seeking approval of the association for inclusion in its accepted list" quotes verbatim the recommendation of the American Council on Education given above as regards teaching schedules and size of classes.

The Association of Colleges and Preparatory Schools of the Middle States and Maryland (*1*) in accrediting colleges makes use of the principles and standards recommended by the American Council on Education. This association has accredited no junior colleges or teacher-training institutions.

The Northwest Association of Secondary and Higher Schools (*1*) in admitting institutions to membership in the association employs the standards recommended by the American Council on Education.

The Association of Colleges and Secondary Schools of the Southern States (*1*) has the following standards as regards teaching schedules and size of classes:

Standards for Colleges of Arts and Sciences

> 7. Number of classroom hours for teachers.—Teaching schedules exceeding 16 hours per week per instructor shall be interpreted as endangering educational efficiency. In general, two laboratory hours will be counted as equivalent to one recitation hour.

8. Number of students in classes.—Classes (exclusive of lectures) of more than 30 students shall be interpreted as endangering educational efficiency.

Junior Colleges

6. Number of classroom hours for teachers.—The average number of credit hours per week for each instructor shall not exceed 16 hours of college work or 18 hours if part of the work is done in high school.

7. Number of students in classes.—The number of students in a class shall not exceed 30 (except for lectures). It is recommended that the number of students in a class in a foreign language shall not exceed 25. The number of students in a laboratory section shall not exceed the number for which desk space and equipment have been provided.

Teacher-Training Colleges

7. Number of classroom hours for teachers.—Teaching schedules exceeding 16 hours per week per instructor shall be interpreted as endangering educational efficiency. In general, two laboratory hours will be counted as equivalent to one recitation hour.

8. Number of students in classes.—Classes (exclusive of lectures) of more than 30 students shall be interpreted as endangering educational efficiency.

The North Central Association of Colleges and Secondary Schools (*1*) has the following standards as regards teaching loads and size of classes:

Colleges and Universities

6. Faculty Service.—The number of hours of classroom work given by each teacher will vary in different departments. To determine this, the amount of preparation required for the class and the amount of time needed for study to keep abreast of the subject, together with the number of students, must be taken into account. Teaching schedules exceeding 16 recitation hours, or their equivalent per week per instructor, will be interpreted as endangering educational efficiency. Institutions which have teachers whose schedules exceed this number must report the facts annually to the secretary of the Commission on Institutions of Higher Education.

7. Sizes of classes.—Classes (exclusive of lectures) of more than 30 students should be interpreted as endangering educational efficiency. Institutions which have classes of larger size shall report the fact annually to the secretary of the Commission.

Junior Colleges

4. Faculty.—The minimum scholastic requirement of all teachers of classes in the junior college shall be graduation from a college belonging to this association or an equivalent, and, in addition, graduate work in a university of recognized standing amounting to one year. The teaching schedule of instructors shall not exceed 18 hours per week; 15 hours is recommended as the maximum.

5. Size of classes.—Classes, exclusive of lectures, of more than 30 students shall be interpreted as endangering educational efficiency. Junior colleges having classes of larger size shall report the facts annually to the Commission.

Institutions Primarily for the Training of Teachers

8. The average teaching program of a teacher in such schools shall not exceed 15 clock hours per week in actual teaching, or the equivalent, in classroom, laboratory, shop, or supervisory instruction. The class unit for instruction shall not exceed 30 students.

The New England Association of Colleges and Secondary Schools (*1*) has the following "minimum requirements for an acceptable college of liberal arts" as regards teaching schedules and size of classes:

> 6. The college should arrange the teaching schedules so that the total number of hours of teaching of any instructor shall vary according to the subject taught, not exceeding 18 hours per week, including extension work and work in other institutions. The college should limit the number of students in a recitation or laboratory class to 30 to each instructor.

The American Association of Junior Colleges (*1*) has adopted the following standard as regards classroom hours for teachers and number of students in classes:

> 7. Number of classroom hours for teachers.—The average number of class hours per week for each instructor shall not exceed 18. Where some time is given to teaching below the college level, as many as 20 class hours per week may be allowed.
>
> 8. Number of students in classes.—The number of students in a class shall not exceed 30 (except for lectures). It is recommended that the number in a class in foreign language and English composition should not exceed 25. The number of students in laboratory sections shall not exceed the number for which desk space and equipment have been provided.

The American Association of Teachers' Colleges (*1*) has adopted the following standard as regards the teaching load of faculty:

> VI. Teaching load of faculty.—The following teaching loads shall be the maximum for a teachers college faculty: Sixteen clock hours per week, or the equivalent. Equivalence shall be based upon the ratio of one class period to one and one-half class periods in shop and laboratory work, one to one and one-quarter in physical education, and one to three-quarters in English composition.

The above citations of the existing regulations show that they do not lead to a uniformity of the teaching load as regards teachers in the departments of chemistry in different sections of the country. In certain sections of the country the existing regulations very often lead to a heavy overloading of the teaching schedules of those teachers who handle laboratory work. Moreover, it is clear that in some sections of the country the teacher handling laboratory work is compelled to assume a far heavier schedule of instruction than is considered permissible for other teachers in the same institution.

In the larger institutions the more elementary classes in chemistry are very large. For lecture periods these classes are brought together as a whole or are divided into fairly large sections. For laboratory work the classes are in general subdivided to a much greater extent. A large part of the work required of many instructors consists therefore in handling these laboratory sections.

Taking the most extreme case, that of an instructor who handles only laboratory work, in order to be credited by the institution with teaching

16 hours, in reality, in certain sections of the country, he would have to teach 32 hours. In following the rule which is said to exist in some institutions, he would have to teach 48 hours. While such extreme cases are never found, the condition seems to be of such frequent occurrence that an appeal for relief from a very heavy teaching schedule is met with the reply that no relief is possible; that the teaching units concerned are quite in accord with the best standard practice (on the basis of two laboratory hours to one lecture hour as suggested by the accrediting association).

The result of this ruling is that many teachers in the chemical departments carry from 20 to 25 clock hours of classroom and laboratory work per week. Some few teachers carry 30 hours, and 14 institutions out of 88 reported that in some cases in their institutions more than two hours of laboratory work were counted the equivalent of one hour of teaching.

In reality, proper instruction in elementary laboratory classes requires a very considerable attention to the laboratory itself, both as regards apparatus and reagents, and constant attention and aid to the students while the work is in progress. Moreover, the notebooks must be examined. Every member of a class does not finish the work assigned during the scheduled hours and perfect attendance is a goal never reached, and therefore some provision for supervising "back" work must be made. It is true the instructor is often provided with assistants who do much of the routine running of the laboratory. Without these assistants the situation could not be endured. Even with their aid the prevailing, and the writer believes almost universal, opinion is undoubtedly to the effect that one hour of laboratory instruction is at least as time-consuming and as tiring as an hour of lecture work.

The student does not receive equal credit toward graduation units in college work for laboratory and classroom work and should not. Usually no preparation on the part of the student for laboratory work is required. In general, as regards the student, it is quite reasonable to consider that two hours of laboratory work is the equivalent of one hour of lecture work. When the student is specializing in chemistry this ratio can sometimes be increased.

In actual practice the present effect of the statement concerning the number of classroom hours for teachers that "In general two laboratory hours will be counted as equivalent to one recitation hour" is to throw on the teachers of chemistry much more than their comparative share of instruction in the institution without securing the slightest recognition for this increased work. In many places it makes effective research work on the part of the instructor an impossibility.

The teaching load carried by professors and instructors in colleges and universities is very often only a part, and often only a small part, of the various activities required by their position. Most men in educational work probably give much nearer 40 than 16 hours per week to the various duties expected of them. To accurately evaluate and adjust these activities is a matter of great difficulty, and classroom hours are at best a poor guide. Even in effecting a balance between the credit allowed for laboratory instruction and classroom instruction no arbitrary rule can be followed. With small advanced classes the instructor may efficiently manage two or three laboratory classes at the same time.

Nevertheless the requirement of the Association of Colleges and Secondary Schools of the Southern States, as it now stands, often works a real hardship. It is suggested that until some better measuring stick be devised this requirement be changed to read:

> Teaching schedules exceeding 16 hours per week per instructor shall be interpreted as endangering educational efficiency. One laboratory clock hour when spent in teaching will be counted as the equivalent of one recitation hour.

Reference

(*1*) "Accredited Higher Institutions, 1927–1928," U. S. Bureau of Education, Bulletin No. **7** (1929).

CHEMICAL PROGRESS IN THE SOUTH

PART II. CHEMICAL PROBLEMS OF SOME SOUTHERN INDUSTRIES

PART II

CHEMICAL PROBLEMS OF SOME SOUTHERN INDUSTRIES

Foreword

J. E. Mills, National Research Council, Washington, D. C.

The writer will attempt no explanation of why the particular problems and industries chosen for brief discussion in the chapters which follow were selected. The fact that the reader would have chosen other problems and other industries causes no concern. What the writer desires to secure is not recognition of the problems, but increased work—planned work—upon any southern industrial problem. The reader therefore should feel quite free to substitute any other problem of any other industry, *provided he seeks to solve the problem chosen.*

A certain general studied with great care with a class of officers the defense of a military position, spending several weeks in detailed consideration of the problem. Three possible methods of attack were found open to the enemy and an adequate defense was provided for each attack. Finally, the general summed up the situation thus: "We have found only three possible methods of attack open to the enemy and you, gentlemen, are prepared to meet these attacks. But your success, gentlemen, will not depend on this. The enemy, he will have found a fourth method. Your success or failure will be determined by the way in which you defend against the method of attack which you have not been able to find." So in research—remember that its success or failure will often depend on finding the fourth method, which apparently does not exist.

The farmer now not only uses chemicals for fertilizer and to fight his crop pests, but to sprout his seeds, to open his flowers, and to ripen his fruit. He adds chemicals to his stock rations to increase their growth and feeds chemicals to his chickens to harden their egg shells. His produce often comes to market with highly specialized chemical coverings and finds its way into a hundred chemical industries as raw materials. But has the farmer himself been benefited by all of this chemistry? Perhaps not much. The automobile and the tractor have added to his pleasure and decreased his labor but they have at the same time deprived him of an income from millions of acres, and have probably been a determining factor in decreasing the value of his land. Rayon or a similar manufactured fiber may yet displace cotton. The once agricultural South has one great problem which transcends in importance any individual problem—the remolding of its agriculture to the demands of a new era.

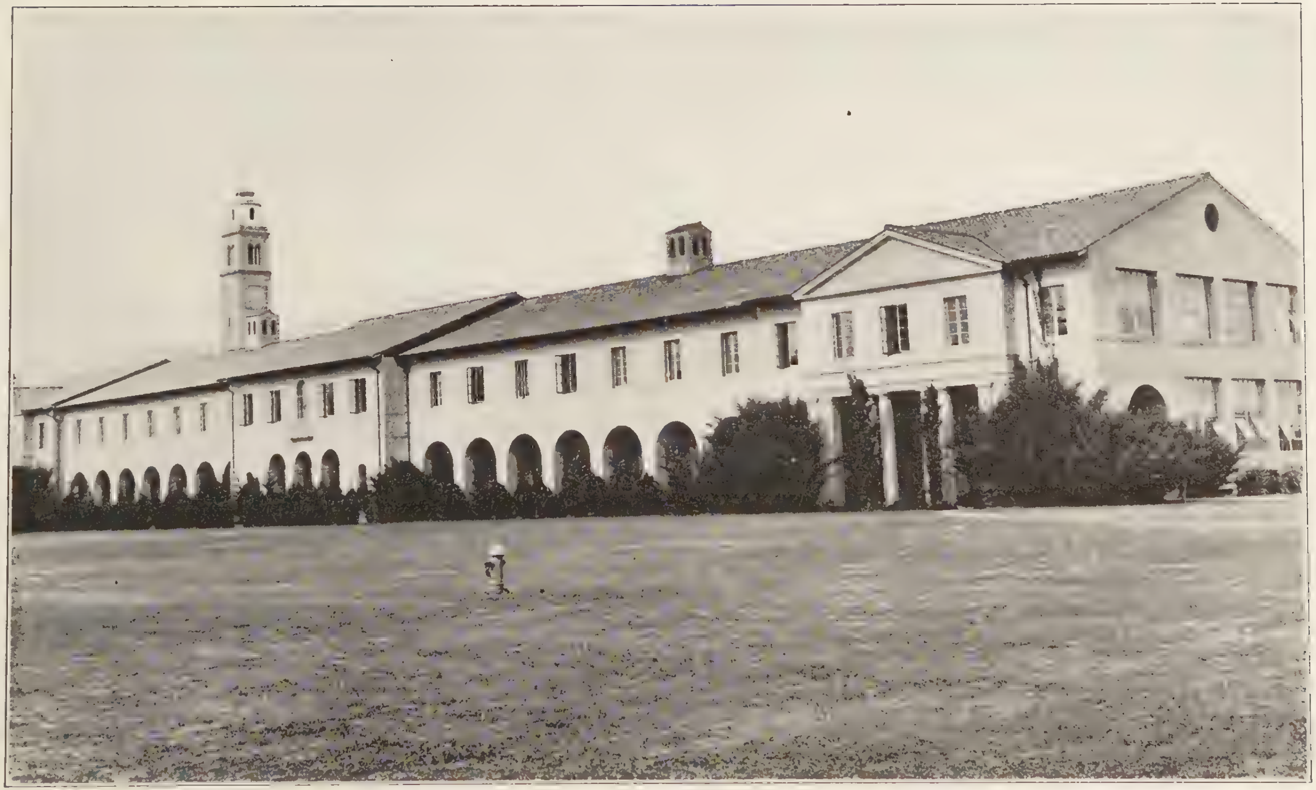

Figure 9.—Chemical Laboratory, Louisiana State University and Agricultural and Mechanical College, Baton Rouge, Louisiana. Erected 1924

CHAPTER V

IMPORTANT INDUSTRIAL PROBLEMS AWAITING SOLUTION

J. E. Mills, National Research Council, Washington, D. C.

Some are inclined to smile when the suggestion is made that lists of research projects should be compiled covering various fields. It is certainly true that most men engaged in research work accumulate rapidly a list of problems that very quickly far surpass the capacity of any individual or staff to solve. The mere accumulation of additional unsolved problems is not a very promising field of endeavor.

It is, however, undoubtedly true that the nature of the problems on which an individual, or a laboratory, concentrates attention has much to do with the success or the failure of the individual or the laboratory. There is no way in which outstanding capacity for successful research is more clearly and definitely shown than in the choice of those problems on which effort is to be expended. No man can foresee clearly the limit, or even the direction, of future scientific or technical advancement. No really able director of a research laboratory ever attempts to place a definite limit on progress. But every director can, and does, continually use the most careful judgment in deciding on those problems on which effort shall be concentrated. Once the problem is chosen there is required the most painstaking and continuous effort to assure that the work required is confined as strictly as possible to those essential elements upon which the solution of the problem really depends. There is a tendency to become quickly involved in a mass of detail which has little to do with the final success or failure of the attack on the problem. Alluring roads continually lead off in directions not conducive to an early arrival at the objective.

Four things seem essential in securing the successful prosecution of research work: Careful selection of the problem for investigation; courage in the expenditure of the necessary time and money; ability to discriminate the important phases of the investigation from the unimportant; and the presence of an eternal question mark at every stage of the investigation. These things often lead to success when a little less would result in failure.

In the field of fundamental scientific investigations and in the continuance of such investigation along paths already marked out there exists a boundless opportunity. When industrial problems are considered there is still abundant opportunity, but there is at once a clear-cut limitation on the problem—it must pay dividends. The dividends are desired in the not-too-distant future.

Many investigators are rendered almost helpless by this limitation. They do not know enough about the business end of the industry. It is difficult for them to realize the cost and trouble of changing a manufacturing process, or of putting a new process on a dividend-paying basis. They are inclined to consider an investigation complete when from a commercial point of view the problem has only begun. It often requires good management to place a laboratory discovery on a dividend-paying basis in five years.

Moreover, the dividend-paying feature which attaches to the solution of an industrial problem places another decided limitation on the investigator. This limitation can be made clear by an illustration. Viewed as an industrial problem it is entirely useless to prove that starch can be produced more cheaply from the sweet potato than corn starch can be produced from corn, if the investigation stops at that point. It is equally important to find the exact use for which the starch can be sold. This may require an intimate knowledge of, and experimentation with, the laundry or textile industry. Ordinarily one man, and often one laboratory, cannot carry out both phases of the investigation. Therefore, industrial problems usually require organization and coöperation for their successful prosecution.

All that has been said is intended to lead up to the following observation: the South has many important problems of an industrial nature requiring chemistry for their solution, but the South has at the present time little organization that will enable these problems to be successfully solved. There are fifty-one industrial research laboratories in the South listed in Bulletin No. 60 of the National Research Council on Industrial Research Laboratories of the United States (1927). These organizations are usually small or are branches of larger organizations in other sections of the country, and their investigations are usually confined to certain strictly limited fields. The South has not sufficiently organized to solve its industrial problems. There is much excellent work at certain educational institutions and experiment stations, but this individual work is not organized and is often not completed, and returns from the work in the way of dividends and increased prosperity are slow.

The point discussed above is of very real importance to the future progress of chemical industries in the South. No organization should ever attempt to limit individual initiative or to dictate the research problems and policies of institutions. But it should be recognized that the problems which require solution themselves place very definite limitations on the success of unorganized effort. The only answer would seem to be definitely organized coöperative effort to include industrial concerns, experiment stations, educational institutions, and certain other state and industrial organizations. Some funds would have to be provided to support such a coöperative effort.

It is with the earnest hope that some organized effort tending to their solution will be made that a few important industrial problems have been selected for brief comment below.

White Paper from Southern Pine

There are now sixty paper mills and thirty-six pulp mills in the South manufacturing paper mainly from the southern pine. Most of it is kraft paper. Discover a process for bleaching this pulp from the pine and a much wider field is opened –newspaper, paper for books, writing paper, and wall paper. The Forest Products Laboratory and certain organizations have made great progress in the solution of this problem. But no industrial problem can be regarded as solved until it is paying dividends. The investigation should be carried to the point of manufacturing and dividends.

Destroy the Toxicity of Cottonseed Meal

Here we have a valuable and rich feedstuff, amounting to approximately 2,000,000 tons a year, obtained as a by-product. It cannot be largely used as a feedstuff because under present feeding practice a certain toxicity becomes evident with the crude meal as produced. There is still some dispute as to the exact cause of this toxicity. There is no need even to outline that discussion here. Find some method of destroying or removing the existing toxicity and you will have added greatly to the value of the cottonseed meal as a feedstuff, and you will enrich the South by millions annually. A real solution to the problem would probably at least double the value of the meal.

Again, we have men claiming that the problem is already solved, and with a considerable amount of evidence to support their point of view. What we need is certainty and dividends.

Doctor Wesson believes (*Cotton Oil Press*, May, 1930) that from this meal a protein food for man can be produced.

Prevent the Deterioration of Cottonseed before It Reaches the Oil Mill

High humidity and high temperature, together, often cause a loss of 20 per cent of the value of the cottonseed to the oil mill before the seed reaches the mill. Surely there is some way of controlling in many cases the temperature and humidity, and preventing deterioration. What is needed here is organized research. Little effort has been expended on this problem. The farmer accepts what is offered for the seed by the oil mill and knows nothing of the conditions which determine its value.

Make the Naval Stores Industry Profitable

According to estimates given, this industry, with an annual output worth $70,000,000, has run at a loss for the last five years on any fair basis of calculation. Also, it is stated that in ten years the industry could be greatly enlarged in size if only it could be placed on a paying basis. There is no necessity here to detail the industrial changes that have decreased the value of turpentine and rosin. Apparently the chemist must be relied upon to place this industry on a paying basis by finding new and more profitable uses for turpentine and rosin.

Production of Phosphoric Acid in the Blast Furnace

The South is intensely interested in any method that will cheapen the production of acid phosphate. Considerable evidence exists tending to show amazingly low costs for the production of phosphoric acid in the blast furnace, and the possibility of a much more concentrated fertilizer that would save greatly in freight bills during the process of distribution to the consumer. All difficulties have not been overcome. Much more work is necessary. The present small-scale plant and manufacturing operations must be extended until finally the process has been adapted to the manufacture of commercial fertilizer.

Means for Utilizing Surplus Perishable Crops

The fruit, berry, and truck crops of the South are enormous. Every so often there is overproduction, resulting in losses reaching into the millions of dollars. The statement has been repeatedly made that a canning factory cannot operate successfully on surplus crops, and the reasons given deserve the most careful consideration. The problem, however, has not really been approached from the right standpoint. The real object to be accomplished is to prevent excessive losses of entire crops. One does not require that a dam to protect from overflow shall pay direct dividends. Its purpose is to avoid the loss of the entire crop. What is needed here is organization and some chemistry. The coming of good roads should somewhat simplify the solution of this problem.

As an illustration, the fact may be cited that a few years ago at certain places in the South truck-loads of the finest peaches already gathered, crated, and delivered at the railroad station, were hauled away and destroyed because the market temporarily would not pay for the cost of shipment. Work has been done in recent years indicating the possibility of freezing peaches and preserving their flavor for use at a later time in the manufacture of ice cream. A somewhat similar process is now widely used with the strawberry. It seems almost sinful to waste that which the world desires.

Better Control of Malaria

Has any real effort commensurate with the importance of the problem been made to improve quinine? A relatively slight increase in the efficiency of that drug would save numerous thousands each year from prolonged periods of ill health, for quinine often does not rid one entirely of the malaria germ and a long period of ill health frequently follows the contraction of malaria.

Surely sufficient results have been attained by chemotherapeutical studies in the past to warrant the belief that this problem deserves serious study. As a matter of fact it has received very little attention. No one understands the specific action of quinine. What is more astonishing, little effort has been made to find out. Perhaps study would show some other chemical, already known, to be more potent and equally harmless. Courage and perseverance would here stand a good chance of ultimate success.

Then there is the problem of controlling the mosquito.

More Complete Utilization of Waste Wood

One of the greatest thrills obtained in a trip through the South was on a visit to the plant of the Masonite Corporation at Laurel, Mississippi—slabs, chips, pine knots, partly rotted wood, bark, all going through conveyors, finally into dividends. The day is surely coming when the waste lumber and rejected wood found so plentifully everywhere in the South will be turned profitably into material of beauty and value.

Cotton Bagging

Jute still comes from India, and the fashions of dress in cotton bales have not changed one iota in fifty years. Many other things have changed. Fifty years ago nearly all of the cotton was shipped North and abroad. Now more than half of the cotton used in the United States does not leave the South before manufacture. But even if the gin were placed beside the mill that is to use the cotton some sort of superstition would insist that jute must be procured from India to be put on that cotton. The writer is skeptical enough to believe that paper could be made of a grade suitable to cover a large part of our cotton crop and that cotton itself could at times be used to advantage.

The entire system of marketing cotton would have to be changed. As is usually the case, the farmer is not quite the fool he seems. He does not imagine that he makes a profit on that jute. He actually does, under our present system of marketing. But somebody finally pays the bill. After all, the farmer is probably the real loser. State-wide organization in the South could handle the marketing end of the problem and such organization is essential to success.

Better Control of Certain Pests

It has been estimated that insect and animal pests in the United States cause an annual loss of $2,000,000,000. The South can boast its share of such pests. On some it has almost a monopoly; others, it shares with other sections of the nation. The following are among the most important insect pests:

- Cotton boll weevil
- Mediterranean fruit fly
- Corn borer
- Cut worm
- Tobacco worm
- Gypsy moth
- Mexican bean beetle
- Mosquito
- House fly
- Red spider
- Cotton aphis
- Coddling moth
- Grain weevil
- Cattle tick

Other pests add much to man's troubles:

- Hookworm
- Disease germs
- Organism causing cotton root rot
- Organism causing anthracnose
- Various molds
- Marine boring organisms such as the teredo

No attempt is made to make this list of man's enemies even approximately complete. Practically every crop has serious pests against which the producer must wage continual warfare. Chemistry must play a major part in their destruction or control. Quarantine, crop management, parasitical control, and mechanical methods are oftentimes extremely valuable aids in controlling pests, but all of these measures, even when applied, leave abundant opportunity for the chemist.

Patient, continued, coöperative effort is required to improve the present methods of combating these pests. Outstanding success is scarcely to be expected even from continued effort. But the annual loss from the pests is so great that probably few expenditures for research really pay dividends as great as those obtained indirectly from research on pest control. Expenditures for such research should be liberal and continuous.

A Larger and Better Ceramic Industry

Recently it was stated that an important ceramic industry in the South was impossible and effort in that direction wasted. The reply was made that there were 13 glass factories now in Oklahoma, and that it looked as if natural gas might offer certain advantages. Attention was called to freight rates on heavy ware such as brick. In reply to this observation a man was cited who had lost all of his money in a brickyard in the South. Since certain brickyards have paid well the argument proceeded.

A generation ago many thought a large textile industry in the South an impossibility. Forty years ago the Carolina Fiber Company of

Hartsville, South Carolina, was organized to make paper from the old field pine because northern manufacturers would not take the pulp offered. That mill is still in operation and there are fifty-nine other paper mills and thirty-six pulp mills.

The question is—"To what extent is the South going to manufacture ceramic ware?" The answer is probably going to depend on the ability of the leaders in the South, and on the demand for such ware, and on little else. There are problems, yes—that is where the ability comes in.

Starch from the Sweet Potato, and into Commerce

The Agricultural Experiment Station of South Carolina showed many years ago the possibility of producing starch cheaply from the sweet potato. The other end of that problem—the sale of the starch—still requires careful investigation. Starches differ. Textile mills in the United States, for the most part, use corn starch for sizing because it is the cheapest starch. Textile mills in Europe use Irish potato starch for the same reason. Can starch from the sweet potato actually be delivered to the textile mills cheaper than corn starch, and will the mills use it? Or can sweet potato starch be made to show properties which would command a special price for special purposes? Also, the sweet potato contains sugar and enzymes. Are these to be used or thrown away? These are the problems for investigation.

The Production in the South of More of the Chemicals Needed by Southern Industry

One industry calls for another. The textile industry makes almost as little use of chemistry as any other large industry. Yet Gilchrist in 1927 (*1*) estimated that the textile mills of North and South Carolina alone consumed $31,500,000 worth of chemicals annually. In manufacturing the chemicals needed by the textile mills of these two states an industry would be required the value of whose annual production would be nearly one-half the value of the entire naval stores industry of the South.

In 1927 Crooks (*2*) estimated that the paper mills of Louisiana and Arkansas alone required yearly 1250 cars of salt cake, 1500 cars of lime, 500 cars of alum, and 75 cars of soda ash. Based on this estimate the paper mills of the South would require more than 13,000 carloads of chemicals a year.

The oil refineries of Oklahoma use (*3*) more than 200,000 tons of sulfuric acid annually and a somewhat similar amount of caustic.

These are but examples of some of the requirements of the new industrial era in the South.

Shead (*3*) stated in 1927 that in the water purification plant at Oklahoma City the lime used came from Missouri, the alum used came from Illinois, the ferrous sulfate from Alabama, and the chlorine from New York. I do not know whether to be glad or sorry that Shead has not investigated the source of the other chemicals used in the South.

The point is that many industries already established require a large increase in the production of the chemicals used in those industries. The opportunity for their manufacture in the South should be carefully examined.

More Technical, Chemical, and Engineering Control of Existing Industries—Textile, Oil Mills, Laundries, Dairying, Etc.

Too many of the industries in the South undertake to save expense by omitting all expert technical control in their processes. If you have any acquaintance at all with such industries you can understand the saving thus made. It may reach several hundreds or several thousands of dollars a year. Also if you have any acquaintance with these same industries you can equally well understand the losses this lack of control occasions. The losses will generally reach ten times the amount of the savings, sometimes much more than that. Reliable analytical laboratories and consulting chemists exist in every southern state. Industries will find it very profitable to make frequent use of the knowledge and facilities now available for checking the quality of materials bought and their own manufacturing operations.

It is just as hard to bring salvation to the captains of industry as it is to the farmers. In either case a few converts have to be made. Others finally notice the difference. Some would rather go bankrupt than change. Some survive because of ability in other directions.

The solution of any one of the problems mentioned above would add appreciably to the wealth of the South. The solution of any five of the problems would probably make a readily visible improvement. Not one of the problems mentioned stands the slightest chance of being solved through the effort of a single individual, though one individual might make outstanding and basic contributions toward the final solution. Among the problems mentioned, that which most nearly approaches the type of problem which could be solved by individual effort is perhaps the investigation calling for better control of malaria. One individual could possibly improve the drug quinine. But the test of such improvement would call for the coöperation of numerous physicians. Other phases of the problem—the control of the mosquito and the treatment of individuals—call for the coöperation of thousands.

The outstanding success of many large organizations and industries has been due in large part to the research organizations which they maintain. A few years ago such a statement would have been questioned.

Today few men would dispute its truth. There should be frank recognition of the fact that few such research organizations exist in the South and that the growth of such organizations as do exist will of necessity be somewhat slow. The writer pleads, therefore, for some organization of existing facilities sufficient to insure the solution of certain technical problems in a reasonable time. No dictation by such an organization as to the work to be done, or the methods of work, is possible or thinkable. Coöperative effort is the only policy that would lead to success.

If the various states, industries, and institutions in the South *organized* to attack the problems mentioned results of importance would inevitably follow. Organized effort is essential in the research laboratories of industrial organizations and it is equally necessary to the effective and rapid solution of the industrial problems of a given locality. Further industrial activity in the South is essential to prosperity. There is no use to tell men not to plant cotton unless you give the individual man something else to do. Fruit and truck are at times more profitable than cotton but on the whole more subject to overproduction and loss. No one seriously disputes the overproduction of grain crops, and automobiles and trucks at present do not consume much hay.

The best thought of the South has been coming more and more to the belief that only one answer is possible to the South—increased industrial activity. All new industrial activity is welcomed. The efforts of leaders during the past few years have produced amazing results. Let the progress continue and as labor learns efficiently to perform new duties end the cry of cheap labor.

Many of the industries of the South are not owned in the South and profits from those industries go to other sections of the country. Why? Partly because of lack of capital in the South, but even more largely, perhaps, because of ignorance of the technical details involved in the industry. The South has not the expert knowledge and large research organizations which have made some of those industries possible. Better libraries must come, more research, increased knowledge.

Only fourteen of many possible problems were selected for brief discussion above. Experts have been asked to state the problems of certain chosen industries and the chapters which follow give many suggestions. But knowledge of any industry always reveals problems. If those chosen for discussion stimulate real effort—planned effort—for the solution of any industrial problem of importance to the South, the purpose of this partial presentation will have been accomplished.

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CHAPTER VI

THE FARMER'S INTEREST IN CHEMISTRY

George M. Rommel, The Industrial Committee of Savannah, Georgia

The earliest manufacturing chemists were the prehistoric men who first placed seeds in the ground, nurtured the plants, garnered the matured grain, stored it, and processed it in one way or another for the sustenance of man and beast. Primitive woman played the part of the laboratory worker and operating engineer, whose daily duties made her familiar with the practical application of chemistry to the conversion of indigestible products of the soil into foods which would not upset aboriginal tummies.

Perhaps the close familiarity of the race with these primeval chemical reactions explains the indifference of most farmers to chemical stories about their main concerns in life. It is no secret that, as a class, books on agricultural chemistry are not in great demand. Agricultural journals run columns on chemical subjects as a sort of vicarious duty to their subscribers, trembling the meanwhile at their "deadliness," as any agricultural editor will tell you.

But we have the perverse fact before us that one of the best sellers in America among agricultural books has for a generation been "Feeds and Feeding," first put out by Dean W. A. Henry of the University of Wisconsin, and now carried on under the direction of his disciple and associate, Dr. F. B. Morrison of Cornell. Dean Henry insisted that technical terms meant something which could not be conveyed by the so-called "popular" substitutes; a farmer was a technician and might just as well get used to using technical terms. So he sang them to his readers and they liked the music. Proteins, carbohydrates, and ether extract, nitrogen-free extract, crude fiber, digestible nutrients, enzymes, and ferments became commonplace notes which made sweet harmony to the livestock farmers. After Henry's overture, it was easy for McCollum and his crowd to get them to listen to the song of the vitamins. And, as a sort of interlude, the ear-splitting Wagnerisms of the Mendelians went over with a bang.

Dean Henry sugar-coated his chemistry. On the title page of "Feeds and Feeding" appeared the old adage, "The eye of the master fattens his cattle." At once he caught his readers' interest, but the amazing thing about the whole accomplishment was that very little of the book could be termed "readable," as best sellers go. "Feeds and Feeding" teemed with the driest sort of stuff on feeding experiments, to which was appended scores of pages of analytical tables, the whole being backed up with a fine index. The book was intended to be used for study and reference like any other handbook or encyclopedia and it was so accepted by farmers.

Henry showed his readers that the correct compounding of livestock rations enabled the farmer to make his feeding operations more profitable. He made chemistry as useful to the feeder as a scoop shovel. He never strayed beyond the intelligence of his audience, and seldom led them very far from the dollar sign pointing toward the highway of profit. His clear, accurate, and terse expressions could be grasped even by simple minds, without any doubt as to what the author meant. For example, an early edition presents this summary to the discussion of the returns in human food by different animals for each 100 pounds of digestible nutrients eaten:

> The cow yields about 139 lb. of milk, containing 18 lb. of solid, practically all digestible.
>
> The pig produces about 25 lb. of dressed carcass. Allowing for water, bone, and gristle, there remains over 15 lb. of edible dry meat.
>
> The steer and sheep yield less than 10 lb. of dressed carcass, nearly half of which is water. Deducting this and the bone and gristle, there remains only from 2.6 to 3.2 lb. of water-free edible meat.
>
> The cow easily leads all farm animals in her power to convert the crops of the field into human food, with the pig second, poultry following, and the steer and sheep coming lowest.

Any child who had been through elementary arithmetic could understand that, and while present-day information has changed the figures somewhat, there has been no change in the fundamental relationships set forth in the last paragraph.

Henry's emphasis on the practical side of chemistry won him the support of his state and laid the foundation for the brilliant chemical research work of the laboratories of the Wisconsin Agricultural Experiment Station.

It is thus apparent that the farmer will listen to chemical stories which have a practical appeal, but they must "register" or he will pass them by.

The alluringly fascinating mystery tales which come out of the chemical laboratory can be matched by the farmer out of his own experience. Can any chemist spin yarns to beat those based on the instinct for well-being and self-preservation which the farmer sees almost daily among the animals under his care?

We have always known that few good pastures are evenly grazed by cattle. Certain portions are eaten closely before others. Chemists have recently discovered that the explanation is that there is more protein in the grass on the heavily grazed sections. The cattle knew long before the chemist learned why they preferred certain grass to others. The farmer assumed that the reason lay in the fact that the closely cropped grass was more nutritious. And he was right, but the farmer won't do anything for the chemist who tells him that, unless he finds something to make the information of practical value—a tip that protein added to the ration will induce cattle to graze the untouched portions of the field, or something like that.

However, protein in grass is a mild story compared with the statements of the experts on beri-beri, who contend that chickens, given the choice between unpolished rice and polished rice, will always pick up the unpolished grains first, thus automatically protecting themselves against the deadly polyneuritis, which is the avian counterpart of human beri-beri. And the humble porker, testing with a critical snout the cafeteria offerings set before him by his owner, puts the human expert to shame and balances his own ration as accurately as it can be done with a scale and pencil and a pad.

Small wonder, then, that the farmer, observing more or less unconsciously the practical rules of chemistry transmitted to him by his forebears and displayed to him by dumb brutes, leaves most of the active thought on the subject to others. But he profits every day because some chemist has worked on his problems. And nowhere is this more a fact than in the South.

No livestock feeding problem in the South surpasses in importance the question of the correct adjustment of the use of oil-bearing seeds in pork production. This is the "soft pork" problem. The highest priced hams produced in the United States come from hogs which have been fed more or less on peanuts or mast. A great deal of the fat in these seeds is soft or even liquid at ordinary temperatures; it retains these characteristics when it is laid down in the tissues of the pig's body. During the curing process, much fat drips from the meat, causing it to shrink seriously in weight. Result, price penalties when the packer buys peanut or mast-fed hogs. This was purely a local southern problem until the popularity of the soy bean as a grazing feed for hogs brought the problem to the front in the corn belt and made it of nation-wide importance.

The method by which the study of the soft pork problem was approached is an important object lesson to those of us who are interested in the solution of national chemical problems.

Supported by the pork producers of the country, the United States Department of Agriculture was able to obtain an appropriation from Congress more than ten years ago. With this start, the project was organized on a nation-wide scale, without duplication or working at cross-purposes. The solution of the problem was recognized at the very start as depending in all probability on pure research in physiological chemistry. No secret was made of this belief, which subsequent events have justified, but so far as the writer can learn, no serious objection to the cost of the fundamental research work involved has ever been lodged by any one connected with the appropriating functions of state or national governments.

The classic instance of the utilization of cottonseed shows that chemistry has added hundreds of millions of dollars to the value of the cotton crop. In fact, some chemists claim that the seed is the more potentially valuable part of the crop, which may in time be a larger source of income to the farmer than the lint. No farmer would now dream of throwing cottonseed away, but there was a time when the cotton farmer refused to take more seed from the gin than he needed to plant the next year's crop, and laws were passed in some states to prohibit the gins from dumping cottonseed in streams.

For a generation, cottonseed oil has been a highly valued human food. Observe now Dr. David Wesson, not content with the laurels which he has already won in the cotton-oil industry, but determined to bring cottonseed meal into its own as a source of human food, and justifying his efforts with a delicious new food product made of cottonseed meal and cottonseed oil, which he calls "Wessona."

Dr. Charles H. Herty has recently made the statement that there is enough protein in a 16,000,000-bale cotton crop to furnish all the protein food requirements for 53,000,000 people for a year. So we have in the cotton crop almost enough protein to supply half the needs of the people of the United States, when and if the chemists show us how this may be done. According to Dr. Herty, a pound of protein in the form of mutton chops costs $3.70. In the form of wheat flour it costs 39 cents, but in the form of cottonseed meal it costs only 5 cents.

Chemists made cotton linters profitable, and this by-product of the cotton-oil industry, which a couple of decades ago was only a nuisance and a bother to the oil man, is now a highly esteemed member of the industrial raw material society for the manufacture of cellulose products. In addition to the value of the linters, cottonseed hulls may soon be in such demand for their cellulose and chemical possibilities that they will no longer be used as cattle feed.

The humble peanut is being analyzed by the chemist as never before. Already a great paper company in the North is planning to grow peanuts on a large scale in the South, ship them north by water, express the oil at the paper plant and there harden the oil into a lard substitute with the by-product hydrogen which the company has not heretofore been able to utilize economically. Chemical products are being sought from the hulls, and the production of xylose from this source promises to develop considerable commercial possibilities.

The cellulose products of the farm beckon appealingly to the chemist. The cellulosic by-products of crop production, straw, cornstalks, cotton stalks, bagasse, etc., usually represent many times the actual weight of the money crop produced. Who, if not the chemist, shall say the farmer shall not burn these by-products and how can the chemist expect the farmer to listen to him, unless he shows that other means of disposal may be more profitable than burning?

It was less than ten years ago that the only use made of sugar-cane bagasse was as indifferent fuel, but the chemist has shown its value as raw material for the manufacture of insulating board, the possibilities of which are not nearly developed.

The passing of the virgin pine forests of the South is being followed with developments in the utilization of sawmill and timber wastes which promise to result in time actually in the production of more building material per acre, year in and year out, decade after decade, than was realized from the virgin forests, with more stabilized and perpetual production, with far greater yields in wealth and with many more men employed than the old Southern timber industry ever knew.

Southern pine trees are coming in for more attention every day. Except where virgin and good second-growth stands are being cut, the principal market for the wood is for paper manufacture—a chemical industry—and the great bulk of raw material for this industry in the South comes from farms. Up until a year ago, every one thought that the use of southern pine for paper making was limited on account of the resin content of the wood. Now comes Dr. Charles H. Herty, with proof that the amount of resin in the sapwood of Southern pine is small, and that the best of all of them for turpentine production, slash pine, has no more resin in the sapwood than northern white pine or spruce.

When protected from fire and hogs, southern pines will grow to pulpwood and turpentining size in 10 to 15 years from seed. Heartwood does not begin to form until the tree is 20 to 25 years old. The significance of these facts is momentous.

If we regard pine wood as a southern farm crop, as we most assuredly must, it would seem that no crop presents greater chemical possibilities. From it we can get pulpwood, turpentine, and rosin. From the waste of the sawmills, perfect lumber is now being produced by a semi-chemical process. In 30 to 50 years, sawlogs can be grown from seed.

Surely not even the cotton plant can surpass our southern pines as working material for the chemist.

The great problem of the naval stores industry, much of whose production is from farms in the South, is to sell the rosin which is produced, and to avoid the production of more than the world's markets can absorb. For every barrel of turpentine, about four barrels of rosin are produced. Rosin is claimed, by chemists who know to be our cheapest source of organic acids, ordinary commercial grades running over 90 per cent in abietic acid. But chemists also tell us that abietic acid has all sorts of untamed habits, such as crystallizing on the slightest provocation and misbehaving badly in other ways when introduced into polite chemical society. Who can make abietic acid behave?

Fossil resins are in wide demand as raw materials for manufacture. They once were as the rosin of the naval stores market now is. How did they get that way, and if we know how, how can the chemist transform fresh vegetative rosin into the equivalent of fossil resin?

There are many more questions which might be asked. Are not these enough?

CHAPTER VII

CHEMICAL PROBLEMS OF THE PAPER INDUSTRY—PARTICULARLY SOUTHERN PINE

JOHN D. RUE, NEWS PRINT SERVICE BUREAU, NEW YORK CITY

The southern pine forests present a most attractive picture as a potential supply of pulp wood. These forests are in many cases well stocked with timber ready for harvest, and with young trees and seedlings to supply the harvests of the future. Foresters tell us that if protected from fire and hogs the forests will produce from one-half to one cord per acre per year, and that they will do this perpetually.

A few simple calculations will indicate what a small area of forest will be necessary to support a relatively large pulp mill. Let us assume a requirement of two cords of wood per ton of pulp, a conservative rate of production of one-half cord per acre and a reserve of forest equal to the area actually required for production. It will become evident that within a thirty-mile radius a mill could be permanently supplied with pulpwood and operate with a daily production of three hundred tons of pulp.

Now contrast that picture with that of the pulp and paper industry as it exists today in relation to its pulpwood supply. Except for sulfate or kraft pulps the industry and its pulpwood supply lie almost wholly outside the region of the southern states. They are found in the New England states and eastern Canada as far west as Minnesota and Manitoba and, more recently, to an increasing extent on the Pacific Coast. Forests of spruce and, to a lesser extent, of hemlock and of fir are depended upon to supply the pulpwood. Mills are going farther and farther each year into the forest areas and away from the markets. Increasing hauls are increasing the cost of pulpwood, for which the New England manufacturer pays from two to three times what southern pine costs at the mill.

The contrast of these two pictures gives good cause for examining very closely into the technical problems involved, not only in the production of pine pulp by processes such as are now used, but also in an attempt to extend the utilization of these species into the manufacture of products for which the rapidly disappearing and increasingly costly spruce finds little competition.

It is fully recognized that a large development of the pulp and paper industry in the South would mean regional changes in the industry at large that would without doubt bring financial hardships to some established operators. But such a situation nearly always attends the growth and progress of an industry, when these changes are brought about by extensive and intensive research. The effect of such research upon the industry as a whole is, however, certain to be an advantageous one. Progressive leaders in the industry will keep in constant touch with the scientific developments and will keep their eyes fixed upon the future. They will be prepared for such regional and process changes as may become necessary.

We may then with full justification point out some of the chemical problems which need solving in the earnest hope that the research facilities of the country may be applied in an increasing degree to their study.

Present Pulping Methods for Pine

Southern pine is pulped almost exclusively by the sulfate process. It is converted chiefly into pulps suitable, by reason of their strength, for wrapping papers and for fiber containers. The brown color which it is difficult to eliminate restricts the uses of the pulp largely to those mentioned.

The South has come to be considered the most important domestic source of these grades of pulp and paper. To a very limited extent, however, southern pine is coming to be recognized as a possible source for strong white pulps, which may compare favorably with similar pulps made from spruce and hemlock.

Problems in the Manufacture of Pine and Sulfate Pulp Wood Composition

Pine, even more perhaps than other species, is far from uniform in composition. There are the differences between heart and sap wood and between spring and summer wood. There are variations in wood density, which become evident by comparing wood produced under different conditions of growth. These variations in wood properties occur even within the same tree.

All such variations affect the pulping operations by introducing variations in the rate with which the wood is penetrated by the digesting liquors and with which the wood substance is attacked by the chemicals. The result is a mass of pulp containing fibers whose properties are unequal, not only by reason of growth conditions but also by reason of the irregularity of chemical action.

Intensive studies are needed, first to extend present knowledge of the chemical composition of the pines, especially as regards such variations as have been pointed out, and second to determine by what means chemical treatments may be applied and controlled so as to counteract to the fullest extent the unavoidable variations.

The Chemistry of the Pulping Process

A great deal has been done toward controlling the chemical engineering factors of the processing, as, for example, temperature, pressure, concentration of chemicals, duration of reaction, etc., in order to arrive at maximum yields and optimum qualities of pulps. Much less has been accomplished toward revealing the actual nature of the chemical reactions which are involved in the attack of caustic soda, sodium hydrosulfide, and sodium sulfide on the various components and constituents of the wood substance. Very much more needs to be done along this line, with a view not only to more intelligent control of these operations, but especially to a successful approach to the conversion of the non-fibrous residue of the digestion into by-products of vastly greater value than that of fuel, to which purpose they are now limited.

There is nothing fantastic in the thought that some day pulp may be the by-product of a complex and important chemical industry—witness the coal-tar industry.

The Production of Strong White Pulps

Pulps prepared by alkaline digestion are difficult at best to convert to a pure white color. There appear to be products of decomposition which fix themselves more or less firmly upon the fibers and stubbornly resist the bleaching action of the usual hypochlorite bleaches. Furthermore, there is some reason to believe that in the pines there are resistant coloring substances which lend to the bleached product a yellowish tint. Efforts to press the bleaching action have resulted, in most cases, in only an indifferent attainment of the desired degree of whiteness and even then at the expense of a very considerable loss of fiber strength and toughness as measured in sheet formation.

Research on this subject, as found in the literature, has developed at least a basis for the method of approach to this problem. In the first place, pulps that are to be bleached must be made under pulping conditions which are somewhat different from those which are best suited to the production of brown kraft pulps. Advantage must be taken of high dilution of the cooking chemicals to effect a minimum degree of absorption by the fibers of the products of decomposition. Despite the dilution, the ratio of chemical to wood must be relatively high in order that the end concentration of unconsumed alkali may be sufficiently high to aid in maintaining the solubility of those products. Details are, however, still too meager and need to be studied from the standpoint, not only of theory, but of economy of operation, especially in relation to the re-use of waste liquors and to the cost of evaporation of those liquors in the process of recovering the chemicals.

In the second place, the methods of bleaching commonly used on sulfite pulps must, to be applicable to sulfate pulps, be materially revised to include bleaching in two stages and the use of regulated values of the acidity or alkalinity of the bleach liquors. Perhaps special supplemental chemical treatments will also be found desirable or essential in the manufacture of products of specific characteristics. There has recently appeared in the literature, especially patent literature, many references to methods of producing alpha cellulose. Some of the literature relates specifically to the production of that material from pine wood pulped by the sulfate process.

The direction and extent of the chemical action produced by the bleach solution are determined in large degree by the pH values of the solution and by the temperature of those solutions. It is possible, therefore, to vary the properties of the product by varying such conditions as those mentioned. Knowledge of the variation in bleaching conditions both as to their effect upon chemical changes and as to their effect upon the properties of the pulps is still very fragmentary and is greatly in need of extension.

Some interesting work has been done toward the use of catalysts in bleaching. It is, however, almost an untouched field of research.

By-Product Disposal and Utilization

Less than 50 per cent of the wood substance is recovered as pulp. The remainder is found, for the most part, dissolved in the waste liquor which is separated from the pulp after digestion, and to a lesser extent passes off as vapor during the digestion or at the time of discharging the contents of the digester. The waste liquor contains also the cooking chemical residues, recovery of which is an economic necessity. The vapors contain turpentine and methanol, and very malodorous organic sulfur compounds. The last greatly hamper prospective manufacturers in the selection of a mill site and give rise to much friction between people of the community and the mill authorities.

Chemical recovery as at present practiced, consists essentially in evaporating the waste liquors, partially burning out the organic matter contained in the thick viscous residue, adding sodium sulfate (hence the name "sulfate" process), smelting the mixture in a reducing atmosphere to transform the sulfate to sulfide and to melt out the sulfide and carbonate of soda, and finally causticizing those compounds in water solution to a mixture of sulfide and caustic.

In the sequence of processes just outlined, no value is developed for the organic matter except a portion of the fuel value. Nearly a fourth of the soda charged to the digesters is lost in the processes of recovery. Much of it passes up the incinerator stacks as volatile or mechanically entrained material. Ill-smelling vapors are permitted to escape from the evaporators and from the incinerators. In the latter case the volatile organic sulfur compounds are supplemented by products of partially burned organic matter which give rise to losses of potential heat values and add to the supply of bad odors.

Some progress has been made toward the development of closed systems for the complete combustion of the organic matter, both solids and vapors, and for the reduction of the incinerator losses to a minimum. The problems involved are essentially of a chemical engineering character rather than purely chemical. They relate to the design of plant equipment for the handling of vapors and for the burning of a thick viscous mass of relatively high water content. They involve also the construction of equipment for the efficient reduction of sulfate to sulfides using the organic content of the mass as the source of heat. Incidentally there are involved problems relating to the selection of furnace linings which will withstand high temperatures in an alkaline atmosphere.

Methods of applying to the concentrated liquors the processes of destructive distillation have been extensively studied, but to only a limited degree have they been applied on a commercial scale. Among the volatile products are acetone, methanol, acetic acid, and various oils.

Very little has as yet been accomplished in any other manner toward conversion of the organic matter in the waste liquors into valuable by-products. The resins of the wood are during digestion converted into sodium soaps. Some effort has been made to salt these out and to purify the soap or the recovered resin, but the results thus far have not been encouraging.

The turpentine content of southern pine pulpwood is quite considerable. It is readily removed from the chips by steam distillation. In fact a large part of it can be and in several cases is being recovered by the simple expedient of maintaining a continuous but limited amount of vapor relief during the earlier stages of cooking. The turpentine is readily separated from the water but offers some difficulty in purification, especially in any attempt to remove completely the dissolved sulfur and the odor which arises from the minute residual content of organic sulfur compounds. The patent literature contains description of methods of fractionation and of oxidation with hypochlorites and other reagents, but the problem is not yet completely solved. While the quantity of turpentine is relatively small it constitutes a potential source of profit which cannot be ignored.

In the causticizing of the recovered soda compounds there is formed a voluminous sludge of calcium carbonate. That sludge should, if sufficiently pure and under favorable circumstances, become the raw material for other processes. In fact, it should be possible to burn it and to re-use the lime thus recovered for causticizing purposes. The sludge usually obtained is, however, far from being pure carbonate. The molten chemicals which flow from the smelting furnace contained dissolved and entrained impurities which are thus added to the crude solution of recovered chemicals. One of the most troublesome of the impurities is iron sulfide which appears to a considerable extent as a colloidal suspension which resists removal by the simpler methods of settling.

The problem of purifying the crude soda solution prior to causticization has not failed to receive attention, but it is worthy of still further study, especially in connection with a study of possible uses for the lime sludge which is formed.

Problems in the Manufacture of Pine Sulfite Pulps

Efforts to pulp pine wood by the sulfite process, *i. e.*, with a solution of calcium bisulfite and sulfurous acid, have not been entirely successful. The chips in nearly all cases are incompletely pulped. It is true that wood from very young trees which are still wholly sapwood yields fairly readily to the sulfite process. The wood from old trees, on the other hand, especially the heart-wood, offers great resistance to the pulping action. Furthermore, the unbleached pulps are yellower and of a less desirable color than are sulfite pulps made from spruce, hemlock, or fir. The pulps bleach with difficulty and are likely to contain slivers composed of bundles of fibers not thoroughly separated from each other and not thoroughly bleached. Attempts to force the bleaching so as to eliminate the slivers result in reducing both yield and strength of the product.

The difficulties encountered seem to go back in all cases partly to the presence of a yellow coloring material in the wood and, more especially, to resinous materials which are unevenly distributed through the wood. These, by reason of their effectiveness in preventing the wood from becoming wetted and penetrated uniformly by the liquor, give rise to uneven distribution of the cooking chemicals and hence lack of uniformity in the pulps. Wide variation in density as between sap and heart wood and between spring and summer wood, add to the irregularities of liquor penetration.

Attempts have been made, experimentally, to remove the resinous materials by extraction with organic solvents or with an alkaline liquor, but in no case have the results which have come to the writer's attention been satisfactory. From a practical viewpoint there is difficulty in obtaining effective extraction with either solvent or alkali when using chips of a size satisfactory for subsequent pulping. Then too, the extractions have not proved to be of much aid to the pulping process. In fact, alkaline treatment results in greatly retarding subsequent pulping with sulfite liquor.

Another difficulty appears in the fact that calcium forms insoluble compounds with the resins and that the products thus formed prevent progressive action by the chemicals as the pulping operation proceeds. Substitution of a soda for a calcium base in the sulfite cooking liquor is advantageous. The sodium resinates are soluble and furthermore the concentration of the sodium bisulfite can be increased beyond that of the calcium base without developing the formation of scale on the piping, and without separating insoluble mineral salts in the pulp. It becomes possible, therefore, to make use of the law of mass action so as to favor the formation of sodium resinates even in slightly acid solution.

The use of soda instead of calcium in the liquor is costly and at once presents the necessity of finding some practicable means of recovering the chemical from the waste liquor. Evaporation of the liquor and incineration of the residue results in the formation of sodium carbonate, sodium sulfite, sodium sulfate, sodium sulfide, and various other sulfur compounds. It is impossible so to control the incineration process as to convert the sulfur compounds to sulfite. Sulfides and sulfates are always formed at the same time and give rise to the formation in solution of thio compounds, some of which are actually harmful in the pulping operation. There is greatly needed a chemical process which will take the waste sulfite liquor from the pulping of pine wood with sodium bisulfite and sulfurous acid and will re-convert the sodium components present in that liquor into sodium bisulfite free from organic material.

A great amount of work has been done on this problem. The patent literature contains descriptions of processes which claim to be satisfactory solutions of the problem, but the writer is not aware of any extensive practical application of them. It is believed that the field is still very much worth cultivating.

A really satisfactory solution of the recovery problem, *i. e.*, from both the technical and economic viewpoint, might make possible a successful application of the sulfite process to pine with the production of a light-colored unbleached pulp suitable for use in newsprint and in other papers which now require a spruce, hemlock, or fir pulp. It might also lead to the use of even a neutral sulfite which has been shown to have some very interesting possibilities in what has been termed semi-chemical pulping.

Problems in the Manufacture of Groundwood Pine Pulps

The most important use for groundwood pulp is in the manufacture of newsprint. Two essential characteristics of pulp for that purpose are a light color and freedom from pitch. Both characteristics are lacking in groundwood pulp made from southern pine. The color is distinctly yellow and the presence of resin and associated material gives rise to endless difficulties due to the segregation of pitch on the mill equipment, especially the paper machine wires and press rolls, causing repeated breakdown of the paper web in process.

In many cases the resinous substances are not excessive in quantity but are very unevenly distributed. Furthermore, the resins proper appear to be associated with fatty substances and the combination to give rise to the formation of sticky masses which are not readily dispersed throughout the pulp. Were it possible to devise some means, perhaps in the form of a protective colloid, which would effectively disperse the resins, the pitch difficulty might disappear.

The color would still be an obstacle to the use of the pulp for newsprint, but some brilliant investigator may find a way to bleach or otherwise remove the objectionable color. It is worth trying.

Other Methods of Pulping Pine

Much has been written about the disappearance of the nation's saw timber supply. Perhaps one answer to the problem will be to reduce cellulosic raw materials to pulp and rebuild them into artificial lumber. There is an abundance of trees. It is only the large, well-formed, and sound ones that are being consumed without adequate replacement. The forest thinnings and the tops and limbs as well as the manufacturing waste from lumber operation are all available in abundance as raw materials for artificial lumber. The pine forests are especially well suited to supply the demands of such processes as may be developed to convert wood into artificial lumber.

Explosion Process.—An interesting example of that kind is the recently developed explosion process. Wood—wood waste is preferred for economic reasons—is subjected to steam at high pressure, *e. g.*, 700 lb./sq. in., for a few seconds, and the steam-impregnated mass released against baffles. The fiber bundles are shattered and the wood reduced to pulp which can be re-assembled into the form of a board, pressed and dried. Practically nothing is to be found in the literature to indicate a detailed study of the chemical changes which occur during the short but very effective period of steaming. Nor is it known what relation there is between the nature and extent of the chemical action and the properties of the completed product. (*See further* Chapter XXVI.)

Semi-Chemical Processes. Less violent methods of attaining somewhat similar results have been developed which involve the mild digestion of wood with relatively neutral chemicals such as sodium sulfite, either alone or mixed with such compounds as sodium carbonate and sodium bicarbonate. Much needs to be learned about the progressive disintegration of the inter-cellular matter in the presence of other chemicals and about the relation of the changes to the economy of the subsequent mechanical treatments which are essential to the ultimate separation of the fiber and to the paper- or board-making properties of the resultant pulps.

These are fields of research which have been revealed by meager preliminary studies but have never received the attention which the evident importance of the artificial lumber industry indicates they should receive.

Problems in Paper Making

There are many problems in the manufacture of paper which are chemical or colloidal in character, but those problems are not likely to be peculiar to the use of southern pine pulps provided the pulping problems are satisfactorily solved. They can therefore be left out of consideration at this time.

The Industry Lacks Research—Not Wood

This review of some of the outstanding chemical problems in the pulp and paper industry of southern pine can leave no doubt as to the need for intensive research if that industry is to attain a merited development. The need is not a cause for discouragement but rather a challenge to the best thought of the chemical fraternity.

There seem to be good grounds for the assertion occasionally found in the literature that there is not going to be a shortage of pulp and paper to the consumer. There is no lack of wood in the forests nor is there likely to be such a shortage. It is true that some of the wood species considered essential for the processes as at present operated show signs of failing to meet the demand. The solution of that difficulty will be found, however, not in curtailed production, but in adaptation of processes to those supplies which are available. Economic pressure coupled with research fostered by far-sighted manufacturers will determine the time and manner of introducing the newer methods.

In this readjustment within the industry there is good reason to believe that the southern pines will play an important part. That belief is strengthened too, by the fact that the pine forests are supplemented by large stands of other species, especially the gums, which also promise to become important factors in pulp and paper making.

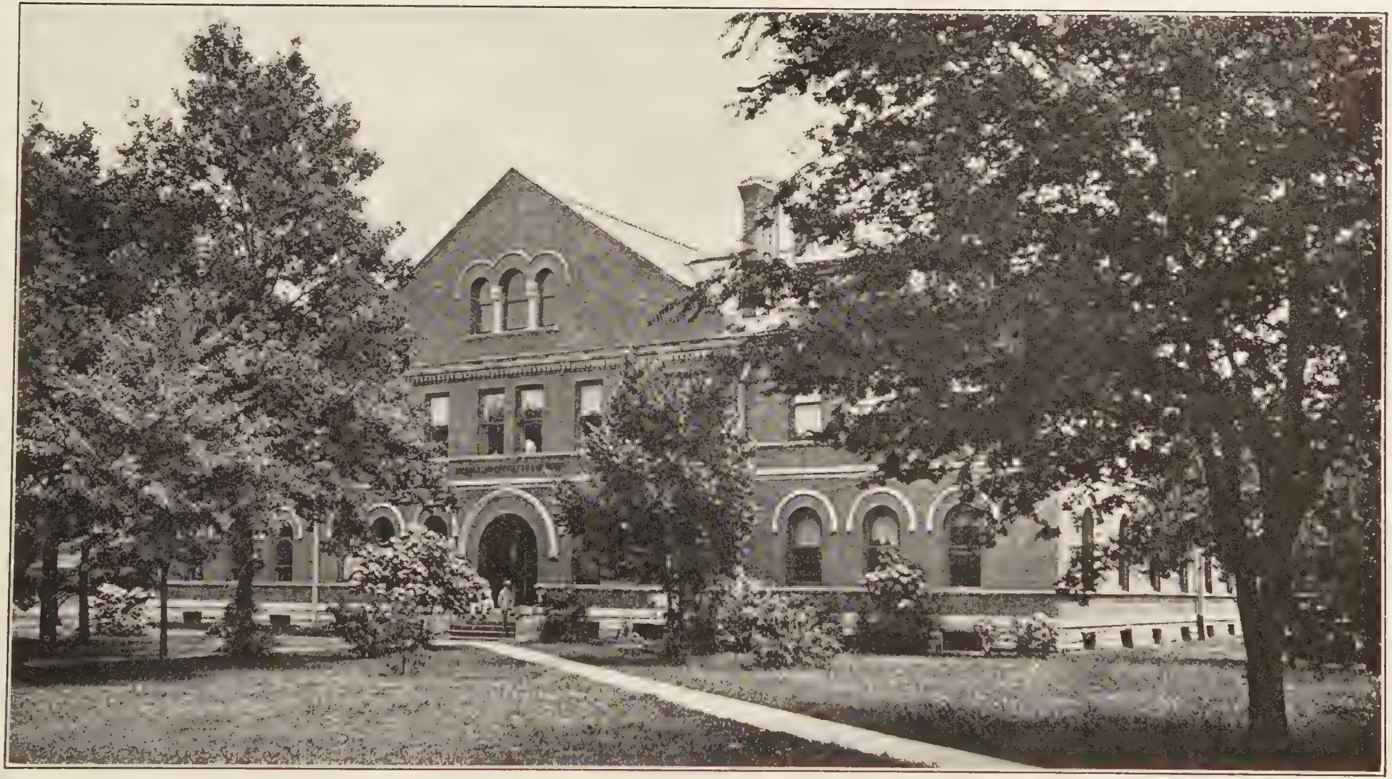

Figure 10.--Richardson Chemistry Building, Tulane University, New Orleans, Louisiana

This building was erected in 1894 and remodeled in 1908. The above photograph is of the building prior to August 25, 1926.

CHAPTER VIII

PROBLEMS IN THE PRODUCTION AND USE OF INSECTICIDES IN THE SOUTH

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The southern states consume the greater part of the calcium arsenate produced in this country and use large quantities of other insecticides but at present do not rank high in the production of these materials. New insecticides are now being developed, however, and the South is the logical place for the manufacture of many of these on account of the availability of raw material and the nearness of the market for the finished product.

Arsenicals

Certain compounds of arsenic continue to constitute the major portion of the tonnage of manufactured insecticides. Nearly 30,000,000 pounds each of lead arsenate and calcium arsenate are produced yearly in the United States. At least 6,000,000 pounds of Paris green are manufactured annually, together with much smaller quantities of magnesium arsenate, manganese arsenate, and zinc arsenite. Calcium arsenate is made from arsenic acid and lime. Arsenic acid is made by oxidizing white arsenic, which is a by-product resulting from the smelting of arseniferous copper ores. White arsenic is not produced in the South but could be brought into the Gulf ports from Mexico, Japan, and Germany at as low a cost as it is now brought into northern ports. About 21,000,000 pounds of white arsenic were imported into the United States in 1928. Lime of high quality is found at many places in the southern states. There seems therefore to be no good reason why calcium arsenate, which is largely consumed in the South, could not be economically produced there.

Calcium arsenate, on account of its cheapness, will doubtless continue to be used for dusting cotton, but non-arsenicals are needed for treating fruits and vegetables. The British government prohibits the importation of apples on which remains an arsenical spray residue equivalent to more than 0.01 grain arsenic (As_2O_3) per pound of fruit. The Department of Agriculture in this country has a higher tolerance (0.017 grain As_2O_3 per pound) but this may be lowered in the future. These restrictions are aimed primarily at lead arsenate which is used for spraying apples, peaches, grapes, and many other products. Lead is a dangerous cumulative poison, and the combination of lead and arsenic in lead arsenate constitutes a health hazard to man or animals eating sprayed fruits and vegetables.

The recent outbreak of the Mediterranean fruit fly in Florida has emphasized another shortcoming in lead arsenate. When lead arsenate is sprayed upon an orange tree the metabolism of the tree is profoundly affected. The fruit formed is deficient in sugar and in acid to such a degree as to become insipid and such fruit has a lower market value than normal fruit.

Tobacco grown in certain regions in the South has been shown to sometimes retain a portion of the arsenical insecticide used to poison the caterpillars that attack the plant. This arsenic may be carried through the manufacturing processes and appear in the finished cigar or cigarette. The injuriousness of a minute quantity of arsenic in tobacco to the smoker has not been proved, but the desirability of finding an effective insecticide which is free from any possible toxic action upon man is apparent.

The position of Paris green in the insecticide field is peculiar. Paris green was the first arsenical successfully used for poisoning insects on growing plants. It came into widespread use against the Colorado potato beetle, and before the insecticidal properties of lead arsenate were discovered, Paris green was used to control such insects as the codling moth in apples. It might have been predicted that lead arsenate and calcium arsenate would supersede Paris green but there is more Paris green used today than ever before. The discovery that Paris green when scattered over the surface of swamps is effective in killing mosquito larvae in the water has greatly stimulated its use and large quantities are used in the malarial regions of Louisiana and other southern states. The green color of Paris green, simulating that of algae, apparently induces the mosquito larvae to swallow the fine particles. For the purpose of mosquito control Paris green does not suffer from competition with other arsenicals, and its larvicidal properties will doubtless increase the demand for it.

Arsenical cattle dip is one of the few insecticidal materials which are used exclusively in the South. It consists of a concentrated solution of sodium arsenite, sodium cresylate and soap, and when properly diluted in water is efficacious in destroying ticks on cattle without injuring the animals. Owing to the efforts of the United States Department of Agriculture the area infested with the cattle or Texas fever tick has been greatly reduced within recent years. Arsenical cattle dip is one of the insecticides for which a diminishing rather than an increasing market may be predicted.

Fluorine Compounds

Non-arsenical insecticides which will be effective in combating chewing insects are urgently needed. A great deal of research is now under way to develop new insecticides of this character. Among materials of mineral origin certain compounds of fluorine appear most promising as substitutes for lead arsenate. Fluorine occurs in the phosphate deposits of Florida and is a by-product in the manufacture of phosphatic fertilizers. Phosphate rock from the southern states contains in addition to calcium phosphate, fluorspar (calcium fluoride), and sand (silicon dioxide). In the manufacture of phosphate fertilizer, this rock is heated with sulfuric acid, which reacts with the fluoride present to form hydrofluoric acid, which in turn reacts with the sand to form gaseous silicon tetrafluoride. As this gas is very destructive to plant and animal life, its escape into the atmosphere is prevented by passing it through water or solutions of chemicals, in which it is absorbed. It has been estimated that phosphate rock contains on an average approximately 60 pounds of fluorine per ton, and as more than 3,000,000 tons of phosphate rock are consumed annually in the United States, there is an ample supply of fluorine for insecticidal purposes. In the form of double fluorides, fluorine has given promising results in dusting tests against the cotton boll weevil, the Mexican bean beetle, the sugar cane borer, and other insect pests. Many investigators believe that a satisfactory substitute for arsenic as a stomach poison to insects may be found among the fluorine compounds. The South is the logical place for the manufacture of fluorine insecticides.

Nicotine

Nicotine, the principal alkaloid in tobacco, is one of the most valuable insecticides that kill by contact. It is extracted from the stems and from the refuse formed in the manufacture of cigars. It is doubtful if tobacco can be grown at a profit for the extraction of nicotine only. Nicotine will probably remain a by-product of the tobacco industry. No complete figures on the production of nicotine are available, but the exports of nicotine sulfate in 1928 amounted to about $90,000.

The production of nicotine may be expected to increase with the production of tobacco, which will doubtless remain one of the principal crops of the South.

Pyrethrum Flowers

The flowers of a species of chrysanthemum, commonly called pyrethrum flowers, contain two esters, Pyrethrin I and Pyrethrin II, which are deadly to many insects but have little or no toxic action upon higher animals and do not injure delicate plants upon which they are sprayed. These esters are the basis of most of the fly sprays now so widely sold in the United States. It has been estimated that the sale of pyrethrum fly sprays amounts to about $20,000,000 annually. Except for a negligible supply from California the pyrethrum flowers consumed in this country are imported from Yugo-Slavia and Japan, the greater part coming from the latter country. The imports of pyrethrum flowers in 1928 amounted to more than 11,000,000 pounds, valued at nearly $2,500,000. Pyrethrum flowers can be grown in the southern states, having been cultivated successfully for a number of years at Arlington, Virginia, but whether their commercial cultivation in this country could compete with that in Japan is doubtful. Hand labor is still extensively employed in harvesting the flowers and Japanese labor is very much less costly than American.

Fish-Poisoning Plants as Insecticides

Certain species of tropical plants used to poison fish contain constituents that are highly toxic to insects. For example, *Derris elliptica* (tuba root), an East Indian plant, and *Lonchocarpus nicou* ("cube"), which grows in the Amazon basin, contain a white crystalline compound called rotenone. This is thirty times as toxic to aphids as is pure nicotine and also exceeds lead arsenate in toxicity to caterpillars. Rotenone when taken by mouth is without effect upon domestic animals, indicating that it is also harmless to man. Fruits sprayed with rotenone would therefore be free from a toxic spray residue.

Rotenone appears to be an ideal insecticide and there is a very large potential market for it.

It may be possible to grow *Derris* and *Lonchocarpus* in southern Florida and, if successful, their cultivation should be highly profitable.

Sulfur

Sulfur in the form of sulfur dust or wettable sulfur or as lime-sulfur solution is a valuable insecticide. Finely powdered sulfur has been used successfully in Texas for controlling the cotton flea, and, in combination with lead arsenate, it is used against the strawberry root weevil and other insects. Lime-sulfur solution for years has been the standard dormant spray material for use against San José and other scale insects infesting orchards. Properly diluted it is a valuable fungicide. The South produces nearly all the sulfur in this country and should manufacture a larger share of the insecticides and fungicides containing sulfur.

Oil Emulsions

Emulsions of petroleum oils are now extensively used in place of lime-sulfur solution for combating scale insects. In California oil emulsions are used instead of hydrocyanic acid for treating citrus trees. In Florida and the Gulf States oil emulsions are used to control plant lice and other insects on citrus trees and in Arkansas and Virginia they are employed against apple pests.

An emulsion of pine oil has been found to be effective against over-wintering larvae of the codling moth. The addition of para-dichlorobenzene to this pine-oil emulsion makes a mixture effective against peach tree borer. The possibilities of pine oil as an insecticide are well worth further study.

New Fumigants

Natural gas in West Virginia is the raw material from which two new fumigants are made. These are ethylene dichloride and ethylene oxide. Ethylene dichloride is replacing carbon disulfide for the fumigation of carpets and upholstered furniture in warehouses, and ethylene oxide appears to be the ideal fumigant for dried fruits and other foodstuffs because it leaves no toxic residue. It may be possible to produce many other insecticides from natural gas, a development in which the South should play a prominent part.

Repellents

The screw worm fly and other blowflies in Texas and the Southwest may be deterred from laying their eggs in wounds on domestic animals by an application of pine tar oil. This oil is a black viscous liquid obtained by the destructive distillation of pine stumps, roots, or wood. The value of this insecticide may be gaged from the fact that this treatment greatly diminishes the loss to the livestock industry caused by blowflies—a loss estimated conservatively at $4,000,000 annually. The production of pine-tar oil and other pine products is confined to the South.

Future Possibilities

The most effective insecticides of the future will undoubtedly be synthetic organic compounds. The starting point for the manufacture of these compounds may be coal tar, petroleum, pine oil, or natural gas.

The southern states are rich in all these raw materials and possess a monopoly of pine oil. Valuable insecticides and fumigants are now commercially prepared from petroleum and from natural gas, and the possibilities of pine oil as a raw material for the syntheses of organic insecticides may be as good as those of the other materials.

Conclusions

Paris green will probably be increasingly used for mosquito control, and calcium arsenate seems destined to hold its own as a cheap cotton-dusting material. A substitute for lead arsenate must be found, however, and new stomach insecticides are needed for the control of the Mediterranean fruit fly, the Mexican bean beetle, the sugar cane borer, the codling moth, the Oriental fruit worm, and many other pests. Fluorine appears the most promising arsenic substitute among the mineral compounds. Rotenone, a constituent of tropical fish-poisoning plants, is both a contact and a stomach poison to insects and on account of its non-toxicity to mammals when taken by mouth promises to be an ideal insecticide.

The South is a large consumer of calcium arsenate, Paris green, and other insecticides and is strategically located for the manufacture of insecticides and fungicides containing fluorine or sulfur, or depending upon petroleum oil, natural gas, or the products of pine distillation as raw materials.

There appears no reason why the South should not manufacture the arsenicals consumed there and also produce many of the newer insecticides.

CHAPTER IX

CHEMICAL PROBLEMS IN CONNECTION WITH THE COTTON TEXTILE INDUSTRY

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The Chemical Constitution of Cellulose

The chemical problems of the cotton textile industry begin with the chemical constitution of the cellulose. It is pretty well recognized that cellulose is built up of anhydro-glucose ($C_6H_{10}O_5$) groups and that four of these groups are united together to form the units which are combined together to form the cellulose molecule, but as yet no one has been able to prove just how these groups and units are arranged and linked together in the cellulose molecule or aggregate. In spite of all that is known regarding the physical structure of the fiber, its X-ray patterns, chemical reactions, etc., this basic chemical problem still remains to be solved.

This particular problem is typical of the numerous other chemical problems awaiting solution in all branches of the cotton textile industry. In fact, perhaps more real scientific research has been done upon this one problem, the constitution of cellulose, than upon any other problem, or many combined problems, in the entire cotton industry. Unfortunately, it must be pointed out that the textile industry itself has contributed very little to the solution of this, or any other, chemical problem. Most of the work upon cellulose has been conducted by a few scientists, rayon chemists, and others employed quite outside of the textile industry.

To many manufacturers and others engaged in the textile industry it may appear that the constitution of cellulose is of no importance to the industry, and it is true that until we learn its exact constitution the value of this knowledge to the yarn manufacturing and weaving plant is problematical. Who can tell what it will mean? It may mean stronger and better fibers and yarns than ever before, which in turn means cheaper and better fabrics. Then again it may mean exactly nothing in this direction or any other as far as the spinning and weaving are concerned.

At the same time, no matter what it may mean directly to the spinner and weaver, we may expect it to be a great deal more important to the synthetic yarn and rayon manufacturers. If this should result in stronger, better, more uniform, and cheaper synthetic yarns and staple fibers, certainly many spinning and weaving plants are in position to benefit very considerably, though indirectly, through less breakage and other difficulties in weaving, which means lower production costs, better fabrics, and fewer seconds.

To the dyer and finisher the chemical constitution of cellulose is much more important than to the spinner and weaver. One reason for this is that even yet we have no universally accepted theory of dyeing cotton or other cellulosic fibers. At the same time, who can predict what chemical finishes or changes may be possible on cotton goods when we have solved the riddle of cellulose? It may result in entirely new and improved methods of dyeing and finishing, or even alter the present methods of yarn and fabric manufacture.

Many believe that we cannot know too much regarding the materials we use in our various processes, and cotton is no exception. Yet until we learn the constitution of cellulose we cannot know the whole story about cotton, no matter how much we study its properties, reactions, impurities, etc. Cellulose is the basic material of the cotton textile industry and almost all that we know about it has been given to the textile industry by those engaged in teaching or research in other industries.

Starch

Closely related to the problem of the constitution of cellulose is that of starch, another of nature's products widely used in the cotton textile industry in sizing yarns for warps, in the finishing of woven fabrics, in textile printing, etc. Just exactly how close the relationship is between cellulose and starch no one knows at present for the reason that we do not know the exact structure of either.

It is pretty well accepted that starch does not consist of a single chemical compound, such as amylose, but no one has as yet been able to prove the exact constitution of even this major constituent. It is very probable that cellulose also consists of a mixture of compounds which we are at present unable to separate.

Nature seldom gives us pure products and neither starch nor the textile fibers appear to be exceptions to this rule. The keratin of wool, the cellulose of cotton, and the fibroin of silk are possibly mixtures of more or less closely related compounds. Just as the rare earths group was at one time considered to be a single element, so we today consider this mixture of compounds, each of which has properties very similar to that of the others present with it, as a single compound. Very probably some day these mixtures may be separated. This separation and the study of each of these compounds is one of the chemical problems of the textile industry.

Another problem in connection with starch is the differences in starches from different sources, their different chemical and physical constitutions and properties. Every textile finisher fully recognizes that there are very great differences between starch from various sources, such as potatoes, wheat, corn, rice, sago, etc., yet practically nothing has been done in the textile industry to discover the causes of these differences. Are they due

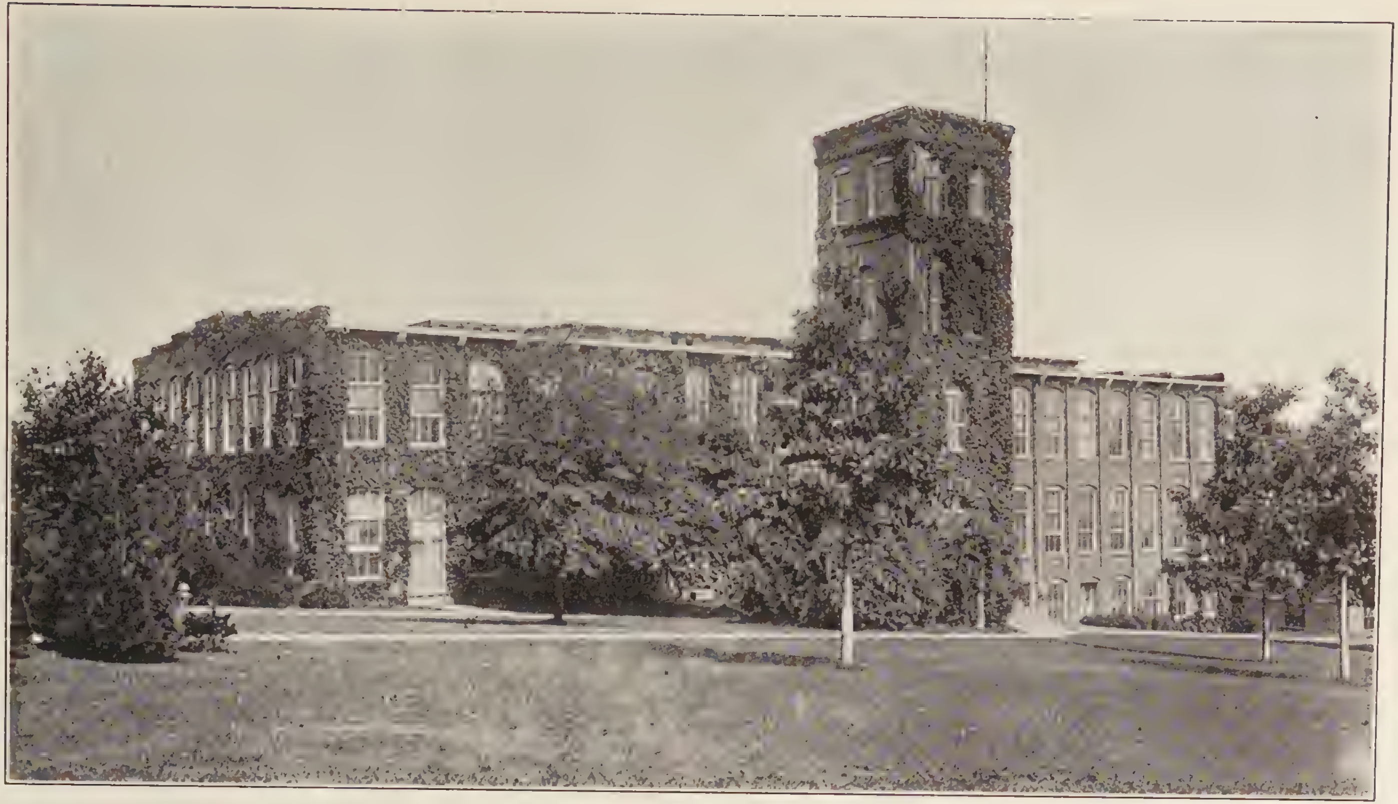

FIGURE 11.—TEXTILE BUILDING, THE CLEMSON AGRICULTURAL COLLEGE, CLEMSON COLLEGE, SOUTH CAROLINA

This is the oldest textile school in the South, and contains an industrial plant for instructional purposes in yarn manufacturing, designing, weaving, textile chemistry, and dyeing.

to physical differences in the form of the molecule or aggregate, the impurities present with the principal constituents in the starch granule, or what—and why?

Sizes and Finishes

While the problems just discussed might be considered by many mill men as of more scientific than technical interest, the modification of the different starches for use in the preparation of various mixtures used in the sizing of yarns and the finishing of fabrics is certainly a matter of direct interest to the mills and mill managements in general.

The natural starch granule is altered by such a simple process as boiling in water, as well as treatment with acids or alkalies, oxidizing agents such as aktivin, hypochlorites, peroxides, certain enzymes, etc. We know that some chemical change takes place in certain of these treatments wherein some or all of the compounds in the starch granule are altered. We know that in most treatments certain of the complex constituents are broken down into simpler compounds, such as dextrins and glucose, but what are the intermediate products? Are the intermediate products the same in each type of treatment and for each starch? What are the chemical and physical properties of these transition products? Are all of the starch components acted upon to the same degree?

Do some of these original or transition products have properties particularly desirable in sizing and finishing compounds? How can we obtain the greatest yield of these particularly desirable products? Which of these transition or end-products are most desirable in your printing pastes? There are innumerable other practical questions along the same and other lines, and when we learn the answers to them we will know a lot more about the subject of sizes, sizing, finishing, etc., than we do today.

At the present time the preparation of sizing and finishing mixtures is conducted almost entirely by empirical methods. Very little information is available upon the relation of the conversion products present to the penetrating, stiffening, or adhesive properties of the various starch pastes. Most American mills buy their sizing and finishing mixtures, which often consist of as much as 90 to 95 per cent water. While it may be necessary, in some cases, to have this proportion of water present in the preparation in order to ship it, in many others it is merely the cheapest addition which can be made, and the purchaser is paying out good money and freight for tons of water each year.

From the above it may be concluded that starch, its conversion products, and water may be the only components of the sizing and finishing mixtures, but such is certainly not the case. Many other components are usually present, such as soaps, waxes, and oils as softeners, vegetable gums, hygroscopic agents such as inorganic chlorides or glycerol, antiseptics such as zinc chloride, weighting and loading agents, etc.

Which of these components are the best, cheapest, or most desirable for each particular mixture and just how much of each should be present? At the present time very little is known on this subject and it has not even been definitely settled in which cases it is most desirable to have the sizing material penetrate deeply into the yarn and where or whether it is most desirable to have most of it remain on the outside of the yarn. Which is most desirable or necessary in your weaving, strength, elasticity, or the mechanical protection of the yarn? If you have definitely settled even this problem in your mill you are considerably ahead of many of your competitors. The sizing of the rayons and synthetic yarns is a quite different and very important problem of the cotton industry.

From the foregoing it may appear that each little mill could—and should—prepare its own sizing and finishing mixtures but, with the present state of our knowledge, unless there is a competent chemist present to control and supervise this manufacturing process the mill may save itself a lot of time, trouble, and money by buying its sizing and finishing mixtures from a reliable manufacturer of these products. At the same time many cotton mills large enough to use a considerable quantity of these products could develop formulas for sizing and finishing mixtures better suited for their particular use than the products they are now using, by manufacturing their own sizes and finishes. At the same time they could save sufficient money to pay several very competent chemists, only a small part of whose time would be necessary for this work. This subject, therefore, constitutes a chemical problem of the cotton textile industry.

Scouring Cotton

The natural fiber as it comes to the cotton mill contains the wax, pectin matter, protein, etc., originally present on the fiber in the boll, as well as some cottonseed oil from the ginning operation. During the course of the spinning and weaving operations more oil, grease, dirt, and foreign materials are collected and, in the case of cotton cloth, generally the "gray goods" also contain more or less sizing applied to the warp in the course of manufacture.

Before this cotton can be hypochlorite-bleached or properly dyed it is desirable or necessary that most of this non-cellulosic matter be removed by a scouring or "bottoming" operation. The nature of this cleansing process varies widely according to the form or condition in which the cotton happens to be, the nature and amount of foreign impurities present, the exact nature of the bleaching, dyeing, or other following process, the result desired, etc. In some cases the scouring may consist of a thorough removal of the size by means of enzymes or acids, followed by a double kier boil. At the other extreme it may consist of merely washing the cloth with soap and water.

Due to the fact that the character of the material to be scoured, the impurities present, equipment available, and the results desired vary so widely, it hardly seems possible that there can be any one best and most economical method to handle all cotton, even in any one form. However, that certainly does not mean that this is not a chemical problem of the textile industry. On the other hand, the very diversity of the conditions render it just that much more of a problem.

To begin with, we do not as yet have any complete theory as to how and why a detergent cleanses. Soap in various forms dates from antiquity and we have had a number of hypotheses which attempted to explain its action but today it is universally admitted that we do not have any theory which explains the whole story of how and why certain compounds remove dirt. Yet almost every branch of the whole textile industry uses detergents to some extent. This theory of detergent action is a very important problem of the cotton textile industry.

Kier Boiling

We have a pretty good idea as to the various impurities naturally present in the cotton fiber with the cellulose, and of the amounts to be expected, but we certainly do not know all that we should regarding just how they may best be removed. A great deal of the cotton is kier boiled at some stage of the manufacturing process, in order to remove these natural and added or collected undesirable materials present with the cellulose in and on the cotton.

Even in the kier boiling almost innumerable formulas and methods are used. We have both the double and single kier boil at pressures of from atmospheric, in the open kier, up to 45 or 50 pounds per square inch. The time may vary from an hour or even less without pressure to as much as 16 to 20 hours for each pressure kier boil. The chemicals used vary from calcium or sodium hydroxide, the latter often combined with sodium carbonate, or the carbonate alone, to various soaps, solvents, and oils used as assistants. Yet we do not even really know anything about the whole process.

We do know that, as would be expected, the double kier boil usually gives much cleaner cotton than the single kier boil and that a souring (acid) treatment before the single kier boil increases its efficiency, but we do not even know which is the best combination of caustic, carbonate, and assistant to give the best and most economical results, which strength of acid is best and most economical, the best combination of time and pressures to use, the most desirable speed of circulation for the liquor, etc. In many cases it has certainly not been proved that the assistant assists at all. In fact it may be that in some cases the so-called "assistant" merely serves as an additional load to be carried by the really active cleansing reagents.

It is believed that emulsification plays an important part in all detergent or cleansing action and it is well known that both the formation and the stability of the emulsion formed are controlled to a very great extent by the hydrogen-ion concentration of the cleansing solution. It is well recognized in the saponification of fat for the manufacture of soap that the highest degree of alkalinity does not always give the best and quickest saponification, and that the speed of saponification is largely dependent upon the degree of emulsification of the fat or oil in the alkali. The kier boiling of cotton, in any form, and the manufacture of soap, apparently have certain points of similarity and it appears possible that a study of some of these factors in connection with kier boiling would be of tremendous interest and importance. Almost nothing along this line has been published and it remains a chemical problem of the textile industry.

Wetting Agents

While on the subject of cleansing it may be well to consider the new wetting agents. Almost innumerable products of this type have been developed within the last few years and they are recommended for almost every purpose, from the manufacture of typewriter ribbons and carbon papers to the printing and finishing of textile fabrics. At the same time we have many varieties of soap, soluble oil, and solvent mixtures, etc., both with and without these new wetting agents.

Undoubtedly, at least some of these products are excellent for many purposes. For certain purposes some one or more of these products may far excel any other reagent at present known for this particular operation. But many of these products are recommended for almost every purpose and it is quite certain that they are not always the best for all of these uses. In fact, it has already been shown that some of them are worse than useless for certain processes. Yet today we have no really satisfactory method of testing either these wetting-out agents or detergent products, so that the whole subject remains a chemical problem of the textile industry.

Bleaching

In the bleaching of all textile materials, cotton as well as all others, there still remain plenty of chemical and other problems. In England the Bleachers' Association and the British Research Association for the Cotton Industry have done some really good work along this line but most of it has not been, and perhaps will not be published. Very little has been done in America upon hypochlorite bleaching except by one very progressive company which has made a thorough study of the preparation or kier boiling of cotton goods containing vat-dyed, colored-effect threads for the hypochlorite bleach. The results of this one study have entirely altered the bleaching procedure in many plants, and in numerous cases the entire method of bleaching, with most excellent results. This example merely serves to show what can be done by research along this one line. Curiously enough, the company which conducted this research manufactures chemicals and cannot in any way be considered a textile concern.

Peroxide Bleaching

In the same way practically all of the research upon peroxide bleaching has been conducted by the chemical manufacturers, rather than by the textile concerns. A great deal of progress has also been made along this line but plenty of problems still remain. The tendering of cotton goods during bleaching by either the hypochlorite or peroxide method, due to the formation of oxycellulose, has certainly not been entirely eliminated and, along with the best, quickest, and most economical method of obtaining the best color (white) remains a chemical problem of the textile industry.

Dyeing

No one can deny that great progress has been made in the discovery of new dyestuffs for use upon cotton but how many advances have been made in recent years in the methods of their application? Almost every change in dyeing methods has been the result of necessity, through the discovery and adaption of new or modified types of dyestuffs by the dyestuffs manufacturers who are constantly pushing research in this direction. The naphthols, soluble vat, and the dispersol type of acetate silk dyes, etc., are examples illustrating this point.

With the exception of the new dyestuffs for acetate silk, which were discovered and developed by the manufacturers of Celanese, the new products have practically all been the result of research by the dyestuffs manufacturers rather than by any branch of the textile industry.

It is very probable that it will be possible to improve upon the methods of dyeing cotton, as well as the other fibers, and it is very likely that research on certain other methods of coloring fabrics, for example, the aniline black process, will give some very unexpected results. In fact, quite recently an ungreenable single-bath aniline black process has been developed. Undoubtedly many other developments in dyeing, aside from the use of the prepared synthetic dyestuffs, are possible in the textile plants.

Viscose Dyes and Dyeing

The fact that improvements in dyeing procedure are possible is well illustrated by the developments, changes, and improvements in the usual commercial practice in the selection of dyestuffs for, and their application to, viscose rayon. The methods now in use are far superior in every way to those in use even less than five years ago but these advances are all based upon the research of only a very few men in England.

Dyeing Theory

As far as the cotton textile industry is concerned, we have as yet no universally accepted theory of dyeing. It is true that very probably no one theory of dyeing, such as the chemical, colloidal, or solution theory, will ever fully explain the phenomena but there is certainly only one reason why we cannot know a great deal more about this important subject than we do at present, and this is the lack of research in the industry itself along the line of dyeing.

In connection with the reactions of cellulose it is very gratifying to chemists to note the remarkable increase in the technical and scientific literature which proves that cellulose is not as inert as some people have been led to believe and that it really has some primary valences which will unite with certain reagents to form true chemical compounds. We hear less and less every year regarding colloidal adsorption in connection with textiles and many other subjects. This is probably due to the more accurate work and better equipment of the more recent researchers.

Permanent Finishes on Cotton

To go back to the subject of finishing cotton goods, which was discussed briefly in connection with the starches, it should be pointed out that we really have no scientific knowledge upon the subject of finishing cotton or any other goods. Even the technical literature on the subject is very scarce. While the finishing methods now in use seem to more or less satisfactorily fulfil the present demands, this is only because nothing better is known and, therefore, it is not demanded by the consumers.

Most of the finishes on cotton goods consist of filling or starching the goods, with or without the addition of softening agents, waxes or other material to give the goods a temporary luster, various calenderings, etc. Of course, practically all of these finishing materials and effects are removed in the first hard washing. On the other hand, in certain cases it is possible to obtain a much more permanent finish on the goods by some other treatment. The proof of this statement is the fact that a few plants have used this permanent finish to a limited extent for some time.

These permanent finishes on cotton can be obtained by the controlled action of various cellulose solvents upon the fabrics, such as strong sulfuric acid, cuprammonium solution, certain concentrated salt solutions, etc. Many similar results can be obtained by the controlled action of a mixture of nitric and sulfuric acids, or by the application of certain cellulose solutions, such as cellulose nitrate or acetate, viscose solution, cuprammonium cellulose, synthetic resins, lacquer-like, and similar solutions.

Almost innumerable unusual, valuable, and interesting effects are possible in this way, not only in finishing but also in printing and dyeing, and many patents have been issued along these lines. However, the few plants which have been successful in this class of finishing have not given out any information upon the subject and in most cases their competitors have not been able to duplicate the results.

Many Effects Possible

In this manner it is possible to transform a cotton fabric into a linen-like piece of goods, give it a wool-like handle and feel, fill a flimsy piece of material until it is opaque enough to be used for window blind material, render a medium-weight fabric translucent, etc. For example, it is possible to print a suitable plain-woven cotton fabric with a solution of cellulose acetate loaded with barium sulfate so that it very closely resembles a piece of damask woven cotton or linen.

These solutions may be applied to the entire piece, as a filling or finish, or printed on in parts only. The various cellulose or other solutions may be loaded and colored, and in almost every case the coated or treated portions dye differently from those which have not been treated, so that many multi-colored and other effects are possible by this method.

Of course, the permanency of these effects varies widely with each particular case but all of them are much more permanent than the usual cotton cloth finishes. Why are they not more widely used? Because most mills have not recognized their value and do not have the technical ability or machinery available to do this work. Furthermore, in the case of many of the patents, considerable research or experimentation is necessary in order to adapt the process to practical mill processes. They are just more chemical problems in the cotton textile industry—which will be solved one of these days.

Mercerizing

While mercerizing is strictly a finishing operation it is possible that more technical information is available on this subject than is the case in so many of the processes just mentioned and yet we have plenty to learn about mercerizing. What strength of caustic, temperature, number, and arrangement of squeeze rolls, tension, speed, etc., give the best and most economical results on each type of fabric or yarn? Are wetting agents necessary or desirable and if so, which and how much should be used? It is true that some very valuable work upon mercerizing has been published and it is very probable that a great deal of the best of this work still remains unpublished, in the files of the companies interested, but the very advances in this field prove that there are still plenty of chemical and physical problems in this branch of the cotton textile industry to be solved.

Oiling Cotton

In connection with the spinning of wool the loose stock is often oiled and there has been some effort to introduce this process into cotton spinning, while the process has been and is used in a number of plants, a great deal of research still remains to be done along this line before it can be definitely stated if, and just where and when, this oiling of cotton is desirable. While this is not strictly a matter of chemistry the preparation of a suitable oil, which is easily removed before bleaching, dyeing, or finishing, is a chemical problem.

The above is merely a brief outline and discussion of a few of the chemical and related problems in the cotton textile industry. There are many others in every branch of the whole textile industry. Every size mixer, bleacher, dyer, mercerizer, finisher, and printer has his own chemical problems and usually no time or adequate assistance to solve them, or to work out new methods or processes.

The solution of many of these chemical problems and the development of new, improved, and better processes and products will undoubtedly be a great step toward success on the part of the textile industry. Probably no other industry in America today is in as good a position to benefit through chemical research and its application as the textile industry, of which the cotton textile industry forms such an important part.

CHAPTER X

CHEMICAL PROBLEMS IN CONNECTION WITH COTTONSEED AND CRUDE OIL

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This article is simply an effort to present a few of the practical problems of cottonseed and its crude products which should be solved by the application of chemistry.

The cotton crop of the United States (*1*) for 1928 expressed in units of 500 pounds gross weight amounted to 14,477,874 bales. The total cottonseed produced was 6,435,000 tons and of this total 5,061,058 tons were crushed at oil mills. The yields obtained by the oil mills per ton of seed crushed are quite variable and depend on many factors. The average for the United States for the cotton crop year of 1928 (statistical year ending July 31, 1929) are given below:

	Pounds per ton of seed	*Value per pound in cents*	*Value per ton of seed crushed*	*Value*
Linters	127	$5.12[1]	$6.51	$25.59 per bale[2]
Hulls	541	0.47	2.54	9.39 per ton
Cake and meal	902	1.99	17.93	39.76 per ton
Crude oil	317	8.35	26.46	0.0835 per lb.
Loss	113	0.0	0.0	0.0

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[1] Calculated assuming a gross weight of 500 lb. to bale.

[2] Running bale.

The value of seed per ton as given in the bulletin referred to is $52.40. This is the value at the oil mill of the crude products after manufacture. The average value obtained by producers is given for the same year as $35.39 per ton. Due to freight and commission the cost of seed to the oil mill would probably be from $6.00 to $8.00 per ton higher than that obtained by the producer.

Cottonseed

There are five variables in the composition of the cottonseed which determine its value to the crude oil mill. These are foreign matter, moisture, oil, nitrogen, and quality. The first four are merely analytical determinations. Methods for these have been so perfected that the crude mill is now operated on a system of chemical control by which the manufacturer determines from his seed analysis what the direct loss will be from foreign matter and moisture, whether the moisture content is low enough to permit him to store the seed with safety, and what his yield in pounds of crude oil, meal, and hulls should be to the ton of raw material. A plan has recently been devised of purchasing seed on a basis of the oil and nitrogen content, using as a basis from which premiums and discounts will be calculated 19 per cent oil and 2.88 per cent nitrogen.

The fifth variable—quality—is still in the speculative field as to control and accurate determination, and offers an opportunity for real research. There are two classes of damaged seed, designated as field-damaged and storage-damaged.

The field damage occurs before the cotton is picked. It is generally caused by excessive wet weather, storms, or freezes while the cotton is open or when the boll is about to open. A breaking down of the glycerides results in an increase in the free fatty acids content. While there is no direct factor connection between free fatty acids and the value of crude oil there is such a close relation that the quality can be estimated with a fair degree of accuracy when the per cent of free fatty acids is known. Field-damaged seed frequently shows high free acids with very slight discoloration of hull or kernel. It is easily possible to produce sound, or, as expressed in the trade, prime meal and hulls from this type of seed, while the oil is badly off in quality, and subject to considerable reduction in price.

Storage damage occurs either in transit, while the seed is in closed freight cars, or in seed houses where the seed is stored in bulk. Here the seed goes through a heat—generally caused by excessive moisture. The combined presence of water, oil, and fiber with exclusion of air really starts a chemical heat that spreads rapidly. Sound dry seed is subject to heating if stored with damp seed. This type of deterioration not only causes an increase of free fatty acids, but discolors the kernels and hulls to such an extent that they are unfit for cattle feed.

The old method in use for years in the industry for grading seed for quality consisted in cutting open one hundred seeds and counting the number showing discolored kernels. This is very crude. It fails to indicate the extent of damage and in the case of field-damaged seed it is often very misleading. During the past two years a system of grading by the free fatty acids content of the extracted oil has been used in the southeastern states with a fair degree of success. The laboratory test is very simple. About one hundred grams of seed are heated in an oven at 110°C. for thirty minutes, then ground in a suitable power mill and the hulls and kernels separated. The oil is extracted from the kernels by percolation with petroleum ether. The solvent is evaporated, the oil weighed, diluted with Formula 30 alcohol, and titrated. The free fatty acids are calculated as oleic acid. Theoretically, this system of grading has considerable merit. It is a wonderful improvement over the old "cut and count" plan. The value, or quality discount, has been arrived at in a scientific manner. Analyses of thousands of samples of crude oil made in various laboratories during the past ten years have been studied by a committee of experienced chemists.

From this work the average color, flavor, and refining loss has been determined for each tenth of per cent of free fatty acids from 2 to 20 per cent. Taking as a basis an established plan of discount for off-quality crude oil, it is a simple matter to convert this discount into a factor for each tenth per cent of free fatty acids in the extracted oil from the seed. This determines with fair accuracy the value of oil made from the seed, assuming that oil showing under two per cent free fatty acids is of satisfactory or prime grade. The weakness of the plan is that the free fatty acids content does not accurately indicate the quality of the other products of cottonseed and it has been necessary to add an arbitrary figure to the factor to take care of this.

This subject is treated in considerable detail due to its importance in the industry at this time. The value of cottonseed produced annually is around two hundred million dollars. As yet no entirely satisfactory system of grading this valuable raw material has been devised. It is the only agricultural product which is not purchased on grade. It is a problem of chemical research to establish this grading system. Mr. G. S. Meloy of the Bureau of Agricultural Economics, United States Department of Agriculture, proposes a plan that will combine quantitative and qualitative values by determining an index of discount or premium. Mr. Meloy's plan is the most promising and progressive one that has been suggested, but it also depends on the free fatty acids as the indication of quality. The plan in detail will be furnished by Mr. Meloy to any one interested.

In order to show the extent of damage which may take place in cottonseed before reaching the oil mill the following report is given showing the average analyses of certain samples of seed in Georgia during one week in the fall of 1929, by districts:

District	*Moisture and foreign matter*	*Free fatty acids*	*Discount*
No. 1	14.10%	1.10%	1.10%
No. 2	13.50	1.70	0.50
No. 3	12.90	3.00	3.00
No. 4	13.30	2.30	1.20
No. 5	13.30	5.50	10.70
No. 6	13.20	8.20	18.80
No. 7	12.30	5.70	11.10
No. 8	11.90	7.00	15.00
No. 9	13.10	8.80	20.70

Linters and Hull Fiber

The short-fibered lint which is ginned from the seed and the even shorter-fibered product removed by grinding and air blast from the hulls, offer an interesting field for research. This lint can be made into pure cellulose, but by present methods the cost and shrinkage in doing so is too great.

Cottonseed Hulls and Hull Bran

Cottonseed hulls and hull bran are other waste materials used principally for cattle feeding. About one-third of the weight of the cottonseed is in the hull. Due to its enormous tonnage this product also offers opportunities. Its possible use as a source of xylose is discussed in Chapter XXXI.

Cottonseed Meal

The cottonseed meal produced contains on the average over 40 per cent protein and 6.50 per cent of fat. Except in isolated instances the meal is used for fertilizer and for feeding stock only.

It has been generally considered that cottonseed meal contains a toxic principle, possibly gossypol, that gives unsatisfactory results when overfed. Recent research indicates that this toxic principle can be destroyed by proper treatment of the meal and that this is largely, if not entirely, taken care of in the usual oil mill practice. When properly fed as a balanced ration no ill effects should follow.

The fact remains, however, that cottonseed meal does not bring the market price it should as a feedstuff, when its stock food value is considered. Its more complete use as a feedstuff is a very important problem.

Doctor David Wesson proposes (*Cotton Oil Press*, May, **1930**) to convert its protein into human food. Such an achievement would have a far-reaching effect on the cost of living.

There remains also for solution the problem of removing from the meal the 6.5 per cent of oil retained in the meal or cake by the present method for pressing out the oil.

Crude Cottonseed Oil

The great practical problem of crude oil is closely allied with that of preserving cottonseed in storage. When subjected to hot weather there is a breaking down of glycerides in the crude oil that makes it very hazardous to keep it in storage for any length of time. Another great opportunity with crude cottonseed oil is the discovery of a method to reduce the expense of converting it into a refined product. The use of a sodium hydroxide solution for this purpose has been practiced for years. The shrinkage or refining loss by this method is too great.

It is beyond the scope of this article to deal with the development and uses of finished products of the cottonseed. Cellulose from linters, refined oil from the crude, and the "soap stock" or fats obtained in the process of refining still offer endless opportunities to the modern research chemist.

Reference

(*1*) The statistics given are taken from U. S. Department of Commerce Bulletin No. **166,** "Cotton Production and Distribution," season of 1928–29.

CHAPTER XI

CHEMICAL PROBLEMS OF THE NAVAL STORES INDUSTRY

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The naval stores industry, one of the key industries of the South, extends from North Carolina through South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and into Eastern Texas. The annual value of its products, rosin, turpentine, pine oil, tar, and pitches, is approximately $70,000,000. Of this total, rosin and turpentine amount to between $50,000,000 and $60,000,000. Approximately 300,000 people in the South are dependent upon the industry for a living. Every farmer in the pine belt is concerned with the economic perpetuation of the industry. Its products are valuable raw materials for the manufacturing of many commodities, chief among these being soaps, varnish, paper size, printing inks, linoleum, insulation materials, polishes, synthetic camphor, and many minor uses.

It is of the utmost importance that this industry be perpetuated on an economic basis. There are millions of acres of idle land throughout this southeastern territory which are not needed for agricultural purposes, many of which will not grow agricultural crops profitably, but will reproduce southern yellow pine. The establishment of a naval stores industry on a profitable basis will make possible the reforestation of these lands.

When these lands produce their second crop of trees, and we have every reason to believe they will, the naval stores industry will be facing a most serious problem, namely, the development of markets which will absorb the production at profitable prices. It is estimated that this country will be capable of producing a million barrels of spirits of turpentine annually in about ten years from now. This is a big increase over the present average production of 600,000 barrels.

Spirits of turpentine is divided into three classes: the gum spirits of turpentine produced from the gum obtained from the living tree; steam-distilled wood turpentine; and destructively distilled wood turpentine; the last two being obtained from stumps and "dead down lightwood." Rosin is produced both from the gum obtained from the living tree and by the solvent process from wood wastes. Pine oil is obtained in both the steam-solvent and the destructive distillation processes. The pitches are obtained from the destructive process and as a residue in the production of rosin oils.

Changes Produced in the Tree

Rosin and turpentine are chemicals, and therefore their study must proceed through chemical research. Such research to be complete should start with the tree. The cause of differing compositions of the crude oleoresins obtained from the two principal species of pine, the longleaf and slash pine, should be determined.

Some trees yield larger amounts of gum than other trees of the same age, size, and general conformation. Fundamental research on the composition of the turpentines from various trees would ultimately prove of value. Some work on this subject has already been started.

The crude gum as it exudes from the tree contains varying percentages of spirits of turpentine. It runs approximately one-third by weight. Much of this is lost in the various steps up to the time of stilling. What is the change in composition of this crude gum between the times of exudation and of stilling?

Spirits of Turpentine

In the case of turpentine some fundamental research has been carried on in connection with the occurrence of the terpenes. However, the field is practically virgin and offers some most attractive problems, both to the organic and physical chemist and to the chemical engineer.

The work naturally divides itself into two distinct classes: one dealing with the methods of production; the other, with problems of an engineering and chemical nature. Data are lacking upon the physical constants of the crude gum, the heat of vaporization and the vapor pressures of the spirits of turpentine, the application to the crude gum of the laws governing fractional distillation, and other information necessary to the proper designing of furnaces, stills, and condensers.

Gum spirits of turpentine is produced commercially from two species of pine: longleaf pine (*Pinus Palustris*) and the slash pine (*Pinus Caribaea*). The original stand of pine with which the naval stores industry started was longleaf pine, and the gum from it yielded a spirits of turpentine, dextro-rotatory. The second growth shows a decided tendency for slash pine to replace the longleaf. However, the slash pine yields a turpentine which is levo-rotatory. Synthetic camphor is believed to require α-pinene for its efficient economic production, at least by existing methods. How will this change in the character of pinene (dextro- to levo-) affect the use of American turpentine for this purpose? *Alpha*-pinene of course occurs in both the dextro and levo varieties. Nor should it be admitted that the present type of synthesis of camphor is the most efficient. It is possible that a contact process might be developed. Basic information, therefore, upon the composition of the present turpentine is essential.

What change, if any, occurs in the composition of turpentine in storage under different conditions? What is the nature of this change? What are the oxidation and polymerization products of turpentine? Residues of distillation of old turpentine show both oxidized and polymerized products.

There are indications that the addition of a small amount of oxidized turpentine to a paint thinner decidedly increases the adherence of the paint to the dense summer woods. What are these oxidation products?

The Federal Naval Stores Act requires proper labeling of spirits of turpentine according to the three classes mentioned. The method of identification of the various turpentines in mixtures is far from satisfactory. This would, of course, also involve a study of the composition of the turpentine to identify some compound as a characteristic ingredient in each.

A study of the several well-known reactions—Friedel-Crafts', Grignard's and Étard's, as applied to the various pinenes; study of reactions relating to the production of sobrerol; of geraniol; carvacrol; of pinonic acid direct from pinene in good yields—would offer an opportunity for good work.

Would it be possible to produce from turpentine a product having a toxic value equal to pyrethrum powder?

Has spirits of turpentine any value in the field of medicine or pharmacy?

Rosin

When we come to rosin we find even less work has been done than on turpentine. We are not sure whether we should say abietic acid or abietic acids. We are far from certain of the structure of this acid. Is the acid as found in rosin the same as occurs in the fresh gum? We know there are several acids but whether they are isomers or distinctly separate compounds is uncertain. A study of the stabilization of abietic acid, or acids, offers an attractive field. We know that some rosins crystallize with difficulty, some readily and some not at all. Why? We recognize a compound termed pyroabietic acid which does not crystallize. Apparently other polymers and isomers exist.

It is only recently that any compounds of abietic acid have been mentioned, the best known of these being an ester made with glycerin. This product has a large consumption in varnish making. Compounds with lime are being studied, and the work is proving very interesting. Studies are being started on the value of aliphatic esters of abietic acid. Ethyl abietate is now being offered on the market and is being used as a plasticizer. A study of the compounds of the other classes of alcohols as well as nitrogen derivatives would be of value. What are the hydrogenation products of rosin or of abietic acid?

Have any of the metals catalytic action on abietic acid? It is known that minute traces of copper acting as a catalyzer have caused trouble in the compounding of rubber. Possibly traces of copper coming from the still in which the rosin was made interfere with the production of many of these esters.

Can rosin find an increased use in the wallboard industry?

Resene

The abietic acid content of rosin varies but would probably average about ninety-three per cent. To the remaining seven per cent we assign the name resene. We know nothing of its composition. A study of this product and properties would be of value. It has been suggested that possibly in the resenes we would find the secret of the transition to abietic acid. Some extremely interesting and valuable work has already been started on this product.

Because of the lack of information available it is impossible to cover completely the field of research available on these two products, abietic acid and resene, alone, disregarding the other naval stores products. Unquestionably, as the work is started the fields will open up and it might prove that the future will see research fields here as important and broad as those of the benzene ring.

Pine Oil

We find in the production of steam-solvent turpentine a product, pine oil, the chief ingredients of which are alcohols: terpineol, fenchyl alcohol, anisole, etc. We find no pine oil in the gum exuding from the tree. There is a most attractive problem in determining what steps take place in the creation of this pine oil. Is it a transition product between turpentine and rosin? If so, is there a connection between pinene and abietic acid?

The Essential Problem

The essential industrial problem is to greatly increase the field of usefulness for turpentine, abietic acid, resene, pine oil, and their possible derivatives, and improve the methods of production. Thus by assuring wider and more profitable markets the naval stores industry could expand until it occupied fully the position which it should take in the profitable utilization of the timber resources of the South.

It seems only proper that the southern colleges and universities should take the lead in developing the studies of the products of the South.

CHAPTER XII

CHEMICAL PROBLEMS OF THE CANE SUGAR AND MOLASSES INDUSTRY

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Cane sugar and molasses production of the continental United States is at present confined principally to Louisiana and Florida. Sugar cane sirup also is made in these states, and in addition is manufactured in Georgia, Alabama, Mississippi, and Texas. A number of chemical problems exist in the manufacture of cane sugar, sirup, and molasses in the United States. These problems are in addition to those of the sugar-refining industry.

Direct White Sugar and Molasses Manufacture

The chemical problems of domestic manufacturers are closely correlated with present economic conditions. Low prices, resulting from world overproduction of sugar, make it imperative for high cost domestic manufacturers to have tariff protection, and tend to bring about various consolidations. Louisiana, with an adequate tariff, could continue to operate as for many years past on the individual plantation basis, with a large number of factories individually operated and products marketed by each plantation without regard to a predetermined and unified plan. The prevailing opinion, however, favors a more progressive policy.

Raw sugar could, if desired, be made the principal product of the domestic cane-sugar industry. Raw sugar, however, is just raw sugar, and the price for it in Louisiana is the same as on the New York exchange. Louisiana in manufacturing raw sugar must compete with Cuba.

For many years certain products which may be called "specialties" have been manufactured in Louisiana. Direct consumption sugar of various grades (not char refined) and commercial sirup and molasses have frequently brought a larger net return than raw sugar. But the market for such specialties has been limited. Grades of "yellow clarified," "plantation white," and "plantation granulated" sugar (made by chemical clarification rather than by char refinery practice) have varied greatly in quality, as also have sirup and commercial molasses (other than blackstrap). Failure to produce uniform grades has tended to limit the demand. Moreover, while both domestic beet sugar and refined cane sugar have been steadily improved in quality, the direct consumption of Louisiana sugar, made by the sulfitation process, has failed to keep pace with modern progress. To improve the quality and uniformity of these Louisiana products, thereby making for greater salability and a somewhat larger net return than results from the manufacture of raw sugar, is a chemical problem, essentially one in the field of colloid chemistry. It includes the investigation of, and the attempt to improve, existing methods of cane juice clarification.

As the growing of sugar cane in Louisiana has recently been put on a more stable basis, owing to the introduction of new and hardier cane varieties, and as sugar production has correspondingly increased, the balance between supply and demand for those specialties which Louisiana is especially well qualified to supply must be restored to enable manufacturers to take advantage of the differential which should exist between specialties and raw sugar. During the past year, for example, more high-grade molasses was made than was in demand at a fair price; consequently, the price dropped to such a figure that approximately as large a return could have been secured by many of these factories by making raw sugar. The remedy for such a condition is a voluntary consolidation of interests, to plan ahead each year for the manufacture in the best-equipped and officially designated factories of only as much high-grade molasses as can be advantageously marketed. The managers of only a relatively few large companies could bargain collectively at the beginning of each season with molasses buyers, thus insuring a fair price and limited output. Similarly, other factories would be properly designed to make either sirup, white sugar, or raw sugar and blackstrap molasses, and to make these products most efficiently. At present the design and equipment of domestic cane sugar factories, taken collectively, are not such that the manufacture of any one specialty can be limited or expanded at will without some sacrifice.

Louisiana interests badly need consolidation and a definite guiding plan. At present the chemist and chemical engineer are greatly handicapped in selecting the most urgent practical problems, and later in applying their findings to proper advantage. Technically speaking, the chemist knows that some kind of improvement is badly needed, but he has great difficulty in ascertaining just what it should be.

The economic phases of the domestic sugar-cane industry have been considered at some length because they are so closely correlated with the manufacturing or chemical problem. The production of direct consumption white sugar and high-grade molasses, for instance, can doubtless be enlarged and made more profitable by chemical research to improve quality, uniformity, and yield per ton of cane; but to make real progress along this line there should be a comprehensive idea of economic factors, careful planning, and a close-knit organization of the manufacturers to stabilize grades and quantity of production. With proper organization and coördination of purpose, a steady and even rapid chemical progress can be expected in the improvement of quality, standardization of grades, and increased factory efficiency.

Sugar Manufacture from Deteriorated Cane

Owing to the seasonal freezes which usually occur in either November or December in Louisiana, an important chemical problem exists in the development of the best method of manufacture for frozen and deteriorated cane. If sugar cane is frozen, and has to remain in the field for some time before delivery to the mill, the juice acidity increases rather rapidly and the percentage of sucrose decreases. The efficient manufacture of any product from deteriorated cane becomes progressively more difficult. In time such cane becomes worthless for milling.

A comprehensive study of the chemical and enzymic changes in sugar cane after a freeze is necessary, the results of such an investigation to be applied subsequently in determining the best method of handling the crop in the field to minimize loss of sucrose. Whether to windrow before or after a freeze, which varieties of cane to mill first, what is the rate of decomposition under different conditions of storage, and other similar problems are questions best answered by chemical work done in close coöperation with the field organization. Clarification of the juice from deteriorated cane is likewise a problem. This kind of chemical work will supply the field and factory managers with the necessary facts by which they can decide, without guess work, what means to take to insure "saving the crop." They may decide it to be wise to provide a factor of safety great enough to save the entire crop during the most unfavorable harvesting season on record. To do this would mean, possibly, improving transportation facilities for the larger factories, a continuation perhaps of certain smaller factories strategically located, an earlier start of the manufacturing season, and an improved field organization so managed as to keep working in the field, rain or shine, with the purpose of keeping the factory supplied with cane regardless of the weather. It would be advisable also to develop an improved process for clarification of juice from deteriorated cane, possibly to provide more ample settling capacity, vacuum pans, etc., to enable the proper handling of "slow working" juices. The wisdom of incurring such additional operating expense can best be judged by chemical data on which to figure operating costs and the yields of sucrose resulting from the various possible ways and means of improving harvesting and production methods.

By-Products

The development of by-products is one of the modern ways of making more profit in any industry. The sugar-cane industry is no exception. Building and insulating board is now manufactured commercially from the fiber of the cane stalk, which was formerly burned as bagasse under the boilers. The price paid for bagasse is still based on the actual cost of replacing it with fuel oil or natural gas. More recently a small quantity of bagasse has been used for the manufacture of artificial silk. It would help the sugar manufacturer to dispose of his bagasse more profitably if the chemist could develop still other uses for this material.

Final, or blackstrap, molasses is now principally used in the manufacture of industrial alcohol and cattle feeds. Methods have been developed for desugarizing molasses, but this disposal of sugar-cane molasses is not profitable with the present prices of sugar and molasses. If the chemist can find other uses for blackstrap molasses, such additional demand will be advantageous.

In other countries cane wax has been extracted from the filter-press muds. In this country the non-sugar solids removed by clarification of the juice and sirup are taken from the presses to the fields for use as fertilizer. The chemist may find a more profitable use for this low-grade by-product.

Such problems as improved analytical and factory control methods are always present in all industries using chemical control. In cane sugar factories, progress along these lines is desired and constantly expected.

CHAPTER XIII

PROBLEMS IN THE FERTILIZER INDUSTRY

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In view of the fact that the larger part of the fertilizer employed in American agriculture is used in the South and that the science of artificial fertilization is more generally practiced there than in other parts of the country, it is a particularly fortunate coincidence that this large area is abundantly provided with a diversity of raw materials for fertilizer manufacture. Certain of these raw materials are already under large-scale industrial exploitation while others yet remaining undeveloped represent industrial opportunities of the future; all of them present problems of research, in some cases for their development, in others for their conservation, and in still others for their more efficient fabrication and more economical utilization.

Concentrated Fertilizers

A problem of fundamental importance in the fertilizer industry as now constituted is the better elimination of those constituents of the completed fertilizer which represent no market value. These constituents, integral parts of fertilizer salts at present unavoidable, are in effect diluents on which the farmer pays freight, sacking, and other costs, the elimination of which would result in a worthwhile decrease in the farmer's fertilizer bill. For example, the familiar superphosphate while made from the highest obtainable grade of phosphate rock, because of its manufacture by treatment with an equal weight of sulfuric acid, is heavily loaded with gypsum. It is sold on the basis of the 16 per cent plant food (phosphoric acid) which it contains and thus carries 84 per cent of diluents.* The same is true to different degrees of other fertilizer ingredients, such, as for example, the familiar ammonium sulfate, containing 21 per cent plant food, sodium nitrate, 16 per cent, and potassium muriate, 50 per cent. The advantages gained are at once evident when the ammonia or the potash is combined directly with the phosphoric acid to form the corresponding phosphates containing 73 to 87 per cent plant food.

The American farmer now pays a bill of over $30,000,000 per year for freight and sacking costs as two items entering into the price of the fertilizer he uses. These items will be cut in two with the doubling of the plant food concentration of the fertilizer he buys, and progressively further reduced with increasing concentration.

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* Throughout this article the conventional fertilizer basis is used in calculating plant food elements, namely, Nitrogen (N), Phosphoric Acid (P_2O_5), and Potash (K_2O).

For many years we have enjoyed a large foreign trade in phosphate rock and likewise in ammonium sulfate. From the modern concept of plant food concentration, both of these commodities are distinctly low grade. How much more logical it would be to extract the phosphoric acid from the rock and combine the acid with the ammonia for shipment abroad as highly concentrated product. America is the only nation possessing within her own borders supplies of both ammonia and phosphates. The world trade in ammonium phosphate should therefore logically be hers. It is alleged that phosphoric acid from the American phosphate rock shipped to Germany for processing is returned to America as a constituent of certain highly fabricated German fertilizers now finding increasing popularity in this market. The cultural value of foreign travel for fertilizer phosphates is a matter the American farmer may properly regard with considerable doubt.

Importance of Physical Characteristics of Fertilizers

The new fertilizer chemicals require study to determine their behavior when combined to form the highly concentrated mixtures now recommended. The farmer demands a product which is granular and free-flowing, one that can readily be distributed by drill. Some of the most desirable of the newer products show a tendency to take up moisture from the air and become sticky or to react with each other and to cake on storing, thus forming a lumpy instead of a granular product. Here is a research problem of the greatest importance, now receiving much attention and justifying even more study, for the successful use of many new products depends on its solution.

Improvement of Machinery for Fertilizer Distribution

With increasing concentration of fertilizer mixtures, improved fertilizer drills are required to give a more exact distribution, for with increase in concentration there is a corresponding decrease in bulk and weight per unit quantity of plant food contained; a more accurate machine is required, therefore, to distribute one-half or one-quarter of the amount required when the old dilute mixtures are used.

Phosphates

The phosphate deposits of the South for a long time constituted the main source of supply of this agricultural essential for both America and Europe. With the exhaustion of the South Carolina deposits, those of Florida and Tennessee have been placed under extensive exploitation. They are easily accessible and are susceptible of mining by cheap methods. High-grade phosphate rock in consequence has become a very cheap commodity for the manufacture of superphosphate, the basis of the American fertilizer industry.

Conservation of Phosphate Deposits

The conservation of phosphate deposits is an essential consideration if regard is had for the future welfare of southern agriculture, for the location of present deposits in close proximity to the agricultural areas where they are mainly used is most fortunate. With the exhaustion of these deposits the essential phosphoric acid must be transported from the Rocky Mountain deposits or from Africa, in both cases entailing long and costly transportation. Such increased cost would greatly affect the future of southern agriculture.

Much excellent research is now being pursued with a view to the better conservation of the deposits and the more efficient utilization of the rock obtained therefrom. Where hydraulic methods of mining are employed in many instances a large proportion of the phosphatic material present is lost through being carried away with the finely divided impurities. This loss may amount to as much as 50 per cent of the total phosphatic content since only the coarser particles are recovered. Flotation methods as an aid to conservation are being introduced with success, being applied to the fines for the separation of the phosphatic from the valueless ingredients.

The enlarged use of agricultural phosphates is desirable so long as that use continues to give the returns in increased yields, reduced labor, and soil conservation at present realized, but the needs of future generations must be safeguarded through efficient utilization of supplies with the elimination of waste. Here is represented a research problem of the first magnitude.

Blast-Furnace Smelting of Phosphate Rock

New methods contemplate the complete utilization of the entire phosphatic strata without separation or concentration. Notable among these is the blast-furnace smelting of phosphate rock for the reduction and volatilization of the phosphorus and its recovery in the pure form. In this new application of the oldest metallurgical procedure the impurities naturally present in the rock serve the useful purpose of a flux for the phosphatic ingredients. The ultimate product, phosphoric acid, in its pure form is ideally adaptable to the treatment of ground phosphate rock for the production of treble-superphosphate, a high-grade calcium phosphate containing 47 per cent available phosphoric acid, as contrasted with the present superphosphate containing only 16 per cent. Or the phosphoric acid may be combined with ammonia to form the ammonium phosphates, containing 65 to 75 per cent plant food, or with potash to form potassium phosphate containing 87 per cent of plant food.

By-products are potentially available in the form of blast-furnace gas applicable to power production or chemical uses; and the slag conceivably can be so adjusted in composition as to approximate that of cement—products which further research may establish as aids to the still cheaper production of fertilizer phosphates.

Treatment of Phosphate Rock with Nitrogen Oxides

Of great promise, likewise, is the new proposal that phosphate rock be treated with nitrogen oxides (from ammonia oxidation) for the simultaneous liberation of phosphoric acid and the fixation of the nitrogen as nitrates, as a substitute for the present treatment of phosphate rock with sulfuric acid to form superphosphate and the present absorption of nitrogen oxides in sodium carbonate to form sodium nitrate, the two operations being combined into one with the elimination of two reagents, both of which appear in the final products as now manufactured as diluents without market value. This method should likewise be applicable to run-of-mine phosphates, particularly so if high concentration in the final product be not regarded as the essential objective.

Nitrogen

With nitrogenous fertilizers the South is already abundantly provided. The nitrogen fixation plants at Hopewell, Va., and Charleston, W. Va., are large-capacity production units planned and constructed for expansion to meet the growing needs of that agricultural empire. Coke-oven ammonia is available in increasing amounts and should continue to become more abundant with increase in the general use of coke—representing a conservation of wide-spread importance as tending toward the elimination of the smoke nuisance and the recovery of valuable by-products. The ammonia oxidizer has now become a familiar plant adjunct as a substitute for the old niter pot formerly common in sulfuric acid plants. Nitrogen oxides are therefore readily available for experimental or large-scale use as a new and cheap chemical reagent particularly attractive from the research viewpoint for application in processes where nitrates may be gotten, possibly as by-products, applicable to fertilizer use. Further research will indicate improvements in utilization of both ammoniates and nitrates with the production of better compounds and the promotion of economies in manufacture, transportation, and distribution.

Potash

For potash, the South is still largely dependent on German-French exports, although her raw materials for potash manufacture are of large proportions and potential importance. Here especially is research required, for foreign competition represents an economic handicap to be overcome only by enlightened technology. Agricultural potash must be cheap. To be cheap it must be produced from cheap raw materials and close to the farms where used, or else it must be a by-product of other manufacture where other products absorb its costs, and in highly concentrated compounds incurring the minimum distribution charge. America's principal known deposit of potash salines at all resembling the German-French deposit (for many years the world's main dependence for potash) occurs in Texas from which in the future may come important potash supplies for southern agriculture. The potash shales of Georgia represent a large resource possessing the great advantage of being situated in the center of the agricultural southeast. Their utilization for the manufacture of agricultural potash awaits further research to point the way. Potash from cement dust is again receiving attention, interest being revived through the development of new and improved equipment applicable to its recovery.

Situated at Baltimore is America's second largest potash plant, producing an excellent grade of vegetable potash as a by-product of the manufacture of alcohol from the fermentation of cane molasses. Here has been demonstrated the entire feasibility of a conservation which quite properly should be extended to include a larger proportion of the very considerable total of this waste material available in the South. The carbonization of cane molasses for the manufacture of decolorizing carbons, applicable to the production of refined sugar, and the recovery of by-product potash has been tested experimentally with results that justify further research. Both from her mineral resources and her agricultural and industrial wastes the South should produce a considerable percentage of the potash required for her agricultural needs.

Organic Fertilizer Ingredients

The use of the organic fertilizer ingredients has always been popular, particularly because of the desirable physical characteristics which they impart to mixtures made up largely of chemical ingredients through overcoming tendencies to cake on storing. Formerly cottonseed meal, animal tankage, fish scrap, leather meal, and garbage tankage were extensively employed. Supplies of these obtainable at fertilizer prices have largely disappeared, due to the diversion of the better of them into stock feeds, where higher prices are received. This is entirely logical and further progress in this direction will result from further research. Of the 34 fish-scrap factories in operation in 1928, with a production of 45,000 tons of scrap and meal, and 3,600,000 gallons of oil, 28 plants are located in the South. The products are susceptible of being refined into higher-grade commodities commanding better prices, and with further research the industry could be promoted to a status more nearly comparable in grade of products to the present cottonseed industry. Other products should be developed to supply the fertilizer industry with its requirements for organic materials. To this end, agricultural, industrial, and municipal wastes of both vegetable and animal origins should be constantly observed for their availability and utilization as organic fertilizer ingredients. Their low analysis in some instances may be counterbalanced in computing their economic importance by the large aggregate tonnages involved.

Other Fertilizer Requirements

The use of relatively pure chemical compounds with the elimination of the various constituents carrying no rated market value may involve the elimination likewise of certain chemical elements in which an occasional soil may be found to be deficient. Certain soils are deficient in calcium (lime); others in magnesium; the Everglade soils of Florida, in some instances at least, respond to copper. The list of essential plant-food elements is rapidly growing beyond the formerly generally accepted trio of nitrogen, phosphorus, and potash. But this is a research problem for the agronomist, for it would not be reasonable to expect the fertilizer manufacturer to add to every mixture all of the elements of plant food just because an occasional soil is deficient in a certain element. Much research is being expended and much more is justified to determine the plant-food requirements of individual soil types and crops.

The Future of the Fertilizer Industry in the South

On the whole, the South enjoys a peculiarly enviable position with respect to large resources in fertilizer materials and abundant supplies of a great variety of chemicals applicable to fertilizer manufacture. Her resources in by-product sulfuric acid and native sulfur are unsurpassed; her phosphate deposits are large and accessible; her nitrogen fixation industry is modern and aggressive and for its further expansion there are vast supplies of coal and natural gas; her potash resources are potentially important; her supplies of raw materials for the manufacture of organic ammoniates are abundant. Every facility is offered for the continuing development of the fertilizer industry as a chemical enterprise utilizing the technic representative of modern progress in chemical science. It is the task of the research chemist to promote this development. The rewards are better and cheaper fertilizers, increased profits, and more profitable agriculture.

CHAPTER XIV

NUTRITION PROBLEMS OF THE SOUTH

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The nutrition of an animal is reflected in its physical condition. Hence, to ascertain the nutrition problems in a given region it is necessary to know something of the physical condition of the people and their domestic animals.

Among the questions that arise in the evaluation of this condition are: What specific deficiency syndromes are peculiar to the region? How prevalent is general malnutrition? Are there indications of a lack of resistance to infections? Are there marked abnormalities of bones or teeth? Is there normal reproduction and rearing of young and do the young grow to the full extent of their hereditary capacity? Then logically follows the query, what factors of climate, soil, dietary habits, or parasitic enemies have either a direct or an indirect relation to the conditions found? These questions should form the basis of our research programs.

The writer is aware of only one nutritional disease that may be considered as peculiar to the South; this is pellagra. There were approximately 7400 deaths in the United States in 1928 which were registered as due to pellagra. Only 227 of these were outside the strictly southern states with 53 of this number in California and 12 in Arizona (*1*). Convincing evidence has not yet been presented that the diet of any class of people in the South is significantly poorer than that of people representing a comparable economic level in any other section of the country. The determination of the basic factors underlying this regional distribution of pellagra are an unanswered challenge.

The available data show that the prevalence of other conditions that may be attributed in part at least to nutritional causes indicate that many dietaries of the South are far from optimum. They do not in general indicate any worse conditions, however, than are found throughout the nation.

Studies made in Mississippi (*2*) show that 30–35 per cent of the groups of rural children examined were underweight, 45–50 per cent had decayed teeth, 57–67 per cent had infected tonsils, and 12–27 per cent showed marked evidence of rickets.

Studies in Virginia (*3*) of 462 white school children show that 85 per cent had defective teeth; the same study shows only 60 per cent with decayed teeth in a group of 323 negro school children. A study of over 5000 negro school children in Atlanta, Georgia (*4*), shows 45 per cent in a good state of nutrition as judged by clinical evidence; 35 per cent were in a fair state;

and 20 per cent in a very poor state of nutrition. Two bony evidences of rickets were found in 12 per cent of the children. Enlarged or diseased tonsils were evident in 32 per cent, conjunctivitis in 15 per cent, and defective teeth in 68 per cent of these children; only 35 per cent had teeth that were classed as distinctly "poor." Other studies in this region are in agreement with the data cited. It is apparent that these clinical examinations on the whole do not show findings that are radically different from those conducted in other parts of the country. A summary prepared by Leete in 1921 from statistics on health examinations of 20,000,000 school children in the United States shows 15–25 per cent of malnutrition and 50–75 per cent of defective teeth (*5*). Of 6000 children examined in a Boston clinic only 11 per cent had perfect teeth (*6*).

The health studies mentioned above emphasize the need for further investigation of the underlying causes of many subnormal conditions of health that are prevalent in the South. Of these perhaps pellagra is the most baffling; while a beginning has been made on this problem, it is only a beginning; its entire solution is not yet in sight. We must also learn more about the causes of decayed teeth, of diseased tonsils, of conjunctivitis, of the various anemias; even the common cold and certain forms of chronic digestive disorders may be included in this category. There is apparently a distinct relationship between these conditions and nutrition. Some of them probably are merely expressions of latent deficiency diseases; others may be the result of secondary infections imposed upon dietary deficiencies of various kinds. The nutrition problems involved in these conditions must be approached through studies on the separate constituents of the diet and the relation of each separate constituent to the diet as a whole.

Vitamin Problems

It is in the field of vitamin research that the answers to many of our nutrition problems may be found. The relation of diet to such conditions as pellagra, defective teeth, diseased tonsils, and some forms of enteritis may in many cases depend upon the vitamin content of the diet. The exact relationships of the vitamins to such conditions should be determined. It is the opinion of the writer that the most important problems in the field of vitamin research at the present time are those dealing with: (1) the further resolution of various vitamin-containing fractions into their ultimate active constituents and (2) the determination as far as possible of the chemical nature and the physiologic functions of these constituents. Happily, actual isolation of the pure substances is not an essential prerequisite to many studies of physiologic functions or of pathologic conditions arising from a lack of the known vitamins. Such studies must at present be considered as valuable chiefly in furnishing a basis for further work rather than as a basis for final conclusions regarding the nature or action of the pure substances.

A most promising phase of this field is a study of the relation of vitamin deficiencies to infection. Many cases of lowered resistance to infections of various natures through lack of certain vitamins are reported in the literature (*7*). There is a general agreement that lack of vitamin A increases susceptibility to infection. Jackson and associates (*8*) presented evidence that lack of vitamin C may also decrease resistance to infection. More recent work in the writer's laboratory (*9*) has shown an apparent association of infection with lack of the vitamin G fraction. Matsumura and co-workers (*10*), moreover, have recently concluded that beriberi is an infectious disease in which a dietary deficiency is merely a predisposing factor. The correct evaluation of these findings must await the accumulation of further data. These infections may be purely secondary invaders of damaged tissues and non-pathogenic even to animals weakened by nutritional disturbances; on the other hand, they may markedly alter the ultimate pathologic picture. It is well that as students of nutrition we do not disregard the possible relation of infectious agents to any of the so-called deficiency diseases. Let us give due consideration to every factor that may have even possible influence upon these conditions.

There is no unanimity of opinion regarding the factors causing tooth decay. It is logical to expect that vitamin D has a profound influence upon the structure and chemical composition of the teeth. This has been proved to be true. Howe (*11*) believes, however, that vitamin C has an important relation to quality of teeth, at least in the guinea pig. It seems probable that several dietary factors have a direct influence upon tooth formation. The relative importance of these various factors should be determined. McCollum has recently emphasized that the only prospect of relief from the present deplorable condition of teeth in America is through increased attention to nutrition during growth, including the prenatal period.

Active rickets is a less serious problem in the South than in some parts of the country. It is entirely too prevalent when our long periods of intense sunshine are considered. Studies of the importance of factors other than vitamin D in the prevention of rickets are essential to a complete understanding of rickets in this region.

Further investigations of the vitamin content of the foods and feedstuffs produced in this region are of importance. The early tests on the distribution of vitamin B need correcting in the light of the more recent fractionation of the old vitamin B group into vitamins B and G. Before these tests can be conducted, the development of suitable methods is essential. These methods should give proper consideration to the fact that vitamin G is probably complex in nature and that the growth-promoting properties of this vitamin fraction cannot arbitrarily be taken as a measure of its pellagra-preventive properties.

All studies of the vitamin content of any material should as far as possible take into consideration the conditions under which the given substance was produced. It is far more important to determine the factors that may affect the vitamin content of a food, than merely to determine the vitamin content of a number of samples of this food selected at random. The effect of soil, fertilizers, season, stage of maturity, and methods of curing, storing, or cooking upon the vitamin content of foods has not been sufficiently studied. It would be of tremendous interest to know if the low organic matter content of our southern soils tends to produce plants that contain subnormal amounts of water-soluble vitamins. A study of the effect of genetic factors upon the vitamin content of plants may likewise prove of importance in determining whether there is a possibility of increasing the vitamin content of certain plants by selection and breeding methods.

The effect of the ration upon the vitamin content of animal products deserves more attention. While the commercial dairymen in this region feed rations that are fair in quality, the average family herd of one to three or four cows is usually very poorly fed; in some cases the sole ration is cottonseed meal and cottonseed hulls in addition to what the cow can gather from so-called pastures; and these pastures are frequently so poor in quality that their contribution to the ration is almost negligible. The quality of the milk produced by such cows should be investigated, for upon the milk from these family herds depends in no small measure the health of a significant portion of our rural population.

Mineral Problems

The South represents largely a region of soils which are relatively low in soluble bases, particularly calcium, and rather low in readily available phosphorus. Probably the most important mineral problem is the determination whether these properties of the soil are reflected in the inorganic content of the food plants. The available data indicate that such a relationship may exist for calcium and phosphorus (*12*). That it is similar for iodine is suggested by the high incidence of goiter in regions where the soil contains an insufficiency of this element. If the plants produced in this region fail to supply sufficient inorganic constituents for normal development of animals, suitable sources of the necessary elements must be determined. The relation of the many inorganic elements to growth, bone formation, tooth structure, and lactation offers an almost unlimited field for research. The function of copper and manganese has only recently been recognized. Other rare elements may play an important but yet unrecognized rôle in the nutrition of animals as well as of plants.

Protein Problems

Perhaps the most important protein problems in this region center around studies of the properties and more efficient utilization of the protein concentrate, cottonseed meal. Many of the early studies on these problems were conducted before the need for vitamins and minerals was recognized. As a result harmful effects were sometimes ascribed to cottonseed meal, which were in reality deficiencies. Various stations are again undertaking a study of these problems with indications of results much more favorable to cottonseed meal than were formerly obtained. Particular attention is being given to the use of this product in rations for poultry, swine, and young calves. At some stations these studies also include work on soybean meal and peanut meal, although these are available in very limited quantities.

Another important problem for study is the nutritive value of legume hays that may be produced on the sandy soils of this region. Many of the leguminous plants cannot be economically grown here. Soybeans, cowpeas, vetch, and kudzu are the most promising. The nutritive value of kudzu particularly should be studied.

Selection of Problems

It should be apparent that there is no difficulty in finding problems; the real difficulty arises in determining what is the most important problem to attack. Too frequently the pressure for information is so great that the investigator undertakes too many projects; as a result a study of the basic principles involved in any of the problems is impossible. Research in nutrition is complicated by numerous factors; many of the problems require the coöperation of the biochemist, the physiologist, the pathologist, and the bacteriologist. The activities of these should be centered around a major research project rather than dissipated over a large number of projects. Fortunately, there is an increasing tendency toward such specialization at some of the southern stations.

Translating Results of Research into Practice

The nutrition problems of the South are by no means research problems entirely. The general adoption of dietary practices that can be recommended in the light of our present knowledge would result in phenomenal improvement in the physical development and health of large masses of people not only in the South but in other parts of the country as well. The modification of dietary habits is a task that is not easily accomplished. Custom, prejudices, economic status, and level of intelligence present obstacles that are almost insurmountable. A prolonged program of evolutionary education will be required for achievement of the ultimate object of our research, an adequately nourished population.

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CHAPTER XV

CHEMICAL PROBLEMS IN CONNECTION WITH TOBACCO

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The tobacco industry in the United States has in the past had the benefit of information from scientific research only in connection with the fertilization of tobacco and to a limited extent in connection with the growing and processing of cigar tobaccos in certain restricted regions. Very little investigation has been carried out in connection with the growing, and more particularly, the processing of cigarette tobaccos of both the Virginia and Burley types grown in our southern states. As the raising of these types of tobacco is essentially a southern industry, it seems appropriate to draw attention to a number of fundamental problems connected with the industry which could be investigated in southern educational institutions and the solution of which should be of benefit to the industry and to the South. I have therefore outlined a number of problems which have presented themselves as suitable for investigation in the course of tobacco research carried out by myself and my associates.

In surveying this situation, the essential distinction between cigar types of tobacco and cigarette types of tobacco must be emphasized as to methods of growing and particularly as to methods used in processing for manufacture. Most cigar tobaccos are fermented by providing suitable temperature and humidity conditions for an actual fermentation, the active organisms or enzymes being those originally present in the green leaf. Most cigarette tobacco on the contrary is processed by flue-curing, which is a drastic thermal treatment sufficient to destroy most of the organisms or enzymes which may have been present. Extensive investigations on the chemistry of cigar tobaccos have been carried out in Germany and in Austria, and are at present being carried out at Krasnodar in Southern Russia. As a general statement, it may be said, therefore, that the technic and methods of investigating cigar tobacco have been fairly well worked out, and that the application of these methods to the cigarette types of tobacco grown in this country presents a very wide and fruitful field for research, which to date has been barely touched upon. In addition to the desirability of repeating such investigations for cigarette types of tobacco, the following specific problems which are here set forth only in brief outline, would undoubtedly repay investigation.

(1) A thorough study should be made of the chemical changes during the process of flue-curing of cigarette tobacco. This should include a study of the moisture changes, as well as the changes in carbohydrates,

total nitrogen, amine and amide nitrogen, and other constituents under controlled conditions of temperature and humidity during the curing process.

(2) An investigation of the effect of fumigants such as are used to control the tobacco beetle upon the tobacco itself ought to be carried out. This should include a study of the absorption of the fumigant by the tobacco in relation to the quantity of fumigant necessary for an effective kill, and a study of the retention of the fumigant by the tobacco as a function of temperature, moisture, and time.

(3) Investigation should be made of the applicability of standard methods of analysis to tobacco. A knowledge of the changes necessary in these methods to make them so applicable would be very desirable. In particular an adequate method for the rapid estimation of moisture in both leaf and manufactured tobacco should be made available.

(4) Though a number of studies of the rate of burn of cigar tobaccos have been made, comparatively few such studies have been made for cigarette tobaccos. An investigation of the factors affecting the rate of burn as related to the composition, and the fertilizers used in growing, presents a problem of great complexity, and one of considerable interest from the standpoint of physical chemistry.

(5) A great number of isolation studies could be carried out upon cigarette tobacco with the aim of identifying the nature and constitution of compounds occurring in tobacco in any of the following classes: (*a*) alkaloids, (*b*) essential oils, (*c*) carbohydrates, (*d*) waxes.

(6) Similarly, a great number of investigations in plant biochemistry suggest themselves since tobacco is in many respects an ideal plant for such investigations. Several of these may be mentioned: (*a*) the effect of the operation of topping in relation to the transfer of constituents in the growing plant both in the stalk and from leaf to leaf up the stalk; (*b*) a study of the factors determining the reversion to type of plants grown in this country from imported seed, such as that of Turkish tobaccos; (*c*) a study of the effect of varying fertilizers on the actual composition of the whole plant; (*d*) the influence of various amounts of nitrogen and potassium on the distribution of nicotine in the plant; (*e*) the translocation of potassium or other mineral constituents such as calcium and magnesium in tobacco plants and its relation to their carbohydrate and nitrogen distribution; (*f*) the influence of chlorine on the general composition of tobacco leaves.

(7) A number of biometric studies could be conveniently carried out in connection with tobacco because of its wide distribution. A study of the relation between the carbohydrate development in the plant and its geographical distribution with respect to temperature, water supply, and atmospheric humidity would be desirable from an economic as well as agricultural standpoint.

CHAPTER XVI

SOME CHEMICAL PROBLEMS OF THE FLORIDA TUNG-OIL INDUSTRY

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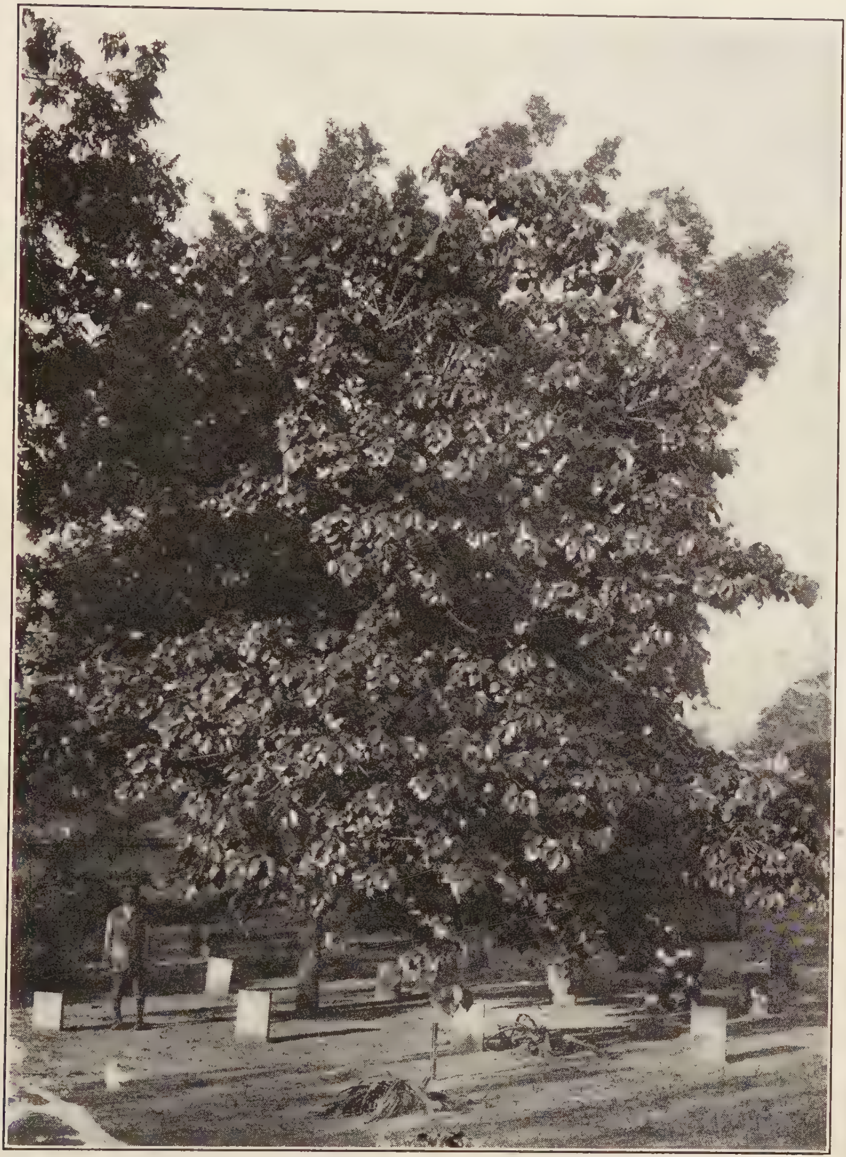
The importance of producing tung oil in the U. S. is evident when it is realized that our paint and varnish industry uses about 100,000,000 pounds of the oil annually, all of which is imported from China. Furthermore, the Chinese oil is not of the highest quality and purity, and the supply is sometimes interrupted by the civil disturbances that have been rather common in that country for the past several years.

Tung-oil trees have been grown to a very limited extent in Florida for a generation or more. Large-scale planting of the trees began in 1923, when 14,000 trees were set out. Expansion of the industry has been steady and rapid, which can be seen from the fact that in 1929 tung-oil groves covered 5500 acres and contained 560,000 trees.

One of the first problems in any industry is that of economical production of a high-quality commodity. The first consideration in the case of tung oil is to raise healthy, prolific trees that will produce a large yield of fruit with a high oil content. This is an agricultural problem in which the chemist must take part on account of the necessity of establishing the relationship of soil and fertilizer composition with tree growth and fruit and oil production.

The next problem is to remove the oil from the fruit as cheaply and completely as possible. According to Mr. B. F. Williamson of Gainesville, Florida, this problem has already been studied to a considerable extent, using equipment and methods that are common to other vegetable oils. Hydraulic pressing has been found unsatisfactory because the cake retains about 15% oil and the oil seals the cloths rather rapidly. Extraction with volatile solvents was abandoned when it was found that the oil assumed the consistency of lard, due, apparently, to the extraction of foreign substances with the oil. The method now in use at the only tung-oil extraction plant in this country (located at Gainesville, Florida) is by use of the Anderson Expeller. This is a continuous process which crushes the previously dried and hulled nuts, producing a light-colored, practically neutral oil. The cake from the Anderson Expeller carries about 5 per cent oil. It is valued at $35 to $40 per ton as a fertilizer on account of the 6 to 6.5 per cent ammonia and the potash and phosphorus it contains. Recently the cake has been found to be of greater value as a source of carbon for case-hardening steel.



American Tung Oil Corporation

FIGURE 12.—A WELL-FORMED TUNG-OIL TREE AT TALLAHASSEE, FLORIDA
This tree was about eight years old when this photograph was taken.

It is quite possible that further improvements might be made in the extraction of tung oil from the fruit and that additional uses for the press cake and hulls might be found which would further increase their value.

Tung oil is an unusual oil because of its high refractive index and its polymerization at high temperature. It would seem well worthwhile to make a careful physical and chemical study of this oil and its fatty acids (*1*). Additional knowledge of the physical and chemical properties of the fatty acids should be of considerable value in understanding the behavior of the oil.

Tung oil is used for a large variety of purposes in China, and its uses in this country are multiplying rapidly. It is the opinion of the writer that the introduction of American tung oil on the market will encourage research that will open up new uses for the oil, both raw and heat-treated, that are not dreamed of at the present time.

The polymerization of tung oil, when heated well over 280°C., is a very interesting phenomenon. The polymerized oil is a dry, gummy mass having about the consistency of art gum. It is practically insoluble in all of the common solvents, and no uses for it are known to the writer. Here is a real problem awaiting solution by scientific research.

It is fairly well known that tung oil, taken internally, is a powerful cathartic. Some insist that the oil is poisonous, while others deny it. A biochemical search of the fruit and oil for the presence of substances having medicinal value should be of considerable interest and such a study might lead to important discoveries.

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(*1*) Scientific Section, American Paint and Varnish Association, Circular No. 358.

CHAPTER XVII

THE RESEARCH FIELD IN CITRUS CHEMISTRY

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The research problems in the field of citrus chemistry may be classed under two general heads—immediately practical problems and fundamental, or more remotely practical, problems. Obviously the line of demarcation between the two types of problems is not sharp; many problems are boundary line problems. Nevertheless, certain questions are of great interest in an industrial way and consequently funds are available for the financing of research on these questions. On the other hand, a number of questions are at present purely of academic interest and means for research along these lines are not so readily at hand.

In the latter category are those problems dealing with the chemical nature of various constituents of the citrus fruits. The essential oils of the orange and of the lemon have received considerable attention in the past, but the oil of the grapefruit, tangerine, and kumquat have at best a scanty background of research literature. These oils are at present of comparatively little commercial importance and consequently there is little incentive for their study except that of academic curiosity. However, it has frequently happened that the commercial significance of certain materials was greatly magnified by a more thorough knowledge of the nature of those materials, and this knowledge has more often than not been attained through the efforts of the academic chemist.

Among the carbohydrate constituents of the citrus fruits, the pectins deserve particular attention. Do the pectins from different natural sources possess identical constitutions? Can the pectins be made to yield derivatives as useful as those of their near relative—cellulose? Just what factor in the pectin structure determines its value as a jellifying agent? These and many other questions on the chemistry of the pectins await solution.

Closely related to the carbohydrate constituents are the glucosides, and these also offer abundant material for research. Their chemical nature and physiological effect, if any, should be at least of academic interest. Can naringenin, hesperitin, or other citrus glucoside products be utilized in any manner which would make their extraction from citrus residues profitable?

Of more than academic interest, however, are numerous problems connected with the utilization of waste products. The canning of grapefruit leaves enormous quantities of waste peels which conceivably offer raw materials for the production of pectin and grapefruit oil. The possibility of utilizing this raw material for the production of grapefruit oil, pectin, stock feed, and fertilizer is distinctly worthy of investigation. Methods of extraction, methods of assaying the raw material, evaluation of the products for their respective uses, and the enlargement of the possible uses to which the products can be put are all urgent problems for study.

The preservation of orange and grapefruit juice over extended periods of time is an exceedingly rich field for work. In the past, the preservation of the latter juice seems to have met with more success than that of orange juice. A careful study of the factors affecting the development of off-flavors in the preserved orange juice and the search for methods for control of these factors appears to be a field in which success will be accompanied by pecuniary reward.

Verging on the field of plant physiology, are found other problems dealing with chemical reactions in the living plant. It has been reported that arsenical sprays cause deterioration in the flavor of citrus fruits, due to decrease in the sugar-acid ratio of the ripe fruit. A comprehensive study of the physiological effects of various spray materials is thus of considerable economic importance to the citrus grower. The employment of ethylene in the ripening of citrus fruits may also be mentioned as deserving of more investigation, since in some quarters this process is considered as still in a problematic stage.

It is obvious that the various questions suggested above cannot be fully discussed in a general paper without throwing undue emphasis on some one phase. It is hoped, however, that the mention of certain problems and the presentment of the actual existence of important problems in the field of citrus chemistry will direct the attention of chemists toward the study of the citrus fruits.

CHAPTER XVIII

SOME CHEMICAL PROBLEMS OF THE CERAMIC INDUSTRY IN THE SOUTH

A. V. Henry, Georgia School of Technology, Atlanta, Georgia

Extending through South Carolina, Georgia, and Alabama are large deposits of sedimentary kaolins which are being increasingly used in the manufacture of ceramic whitewares and refractories, and as a filler for paper, rubber, and linoleum. In recent years, these kaolins have found wide application for coating paper. Approximately three-fourths of the domestic production of such clays comes from Georgia and South Carolina. The sedimentary kaolins of the South are of several distinct types and are classified as hard, semi-hard, soft, and bauxitic. Due in a large measure to the ease of refining, the soft kaolins are most generally used in the whiteware and paper trades. The hard kaolins are more commonly distributed and while they are widely utilized in the manufacture of refractories and to a lesser degree in ceramic whitewares, would find a greater market if some economical method of refining could be developed. Refining by water flotation is the usual and probably the most efficient method. The hard kaolins are relatively dense and are essentially colloidal. These characteristics necessitate increased blunging for complete disintegration into a homogeneous slip and the colloidal nature of the clay makes filter pressing difficult. The use of electrolytes, limited aging, and heating have possibilities.

Southern sedimentary kaolins have a color varying from white to ivory. For the manufacture of ivory tableware and sanitary ware and for ivory-tinted paper, the kaolins having a color other than white are satisfactory. Much of the kaolin industry, however, depends upon the whiteness of the clay in both the raw and fired condition. Chemistry, in many cases, must be relied upon to bring about this color improvement.

The first bauxite discovered in the United States was in northwestern Georgia in 1887. Since that time most of the known deposits of high-grade bauxite have been mined out in this state. Practically the whole of the domestic production now comes from Arkansas with small quantities being produced in Alabama. Mississippi has bauxite reserves but little has been done to develop them. In these southeastern states are large deposits of low to medium grade bauxite varying in alumina content from 45 to 52 per cent. Deposits of this grade are satisfactory for the manufacture of bauxitic refractories. For the production of aluminum, which offers the greatest market, a higher grade is necessary. An economical method of enriching the ore would permit the operation of many de-

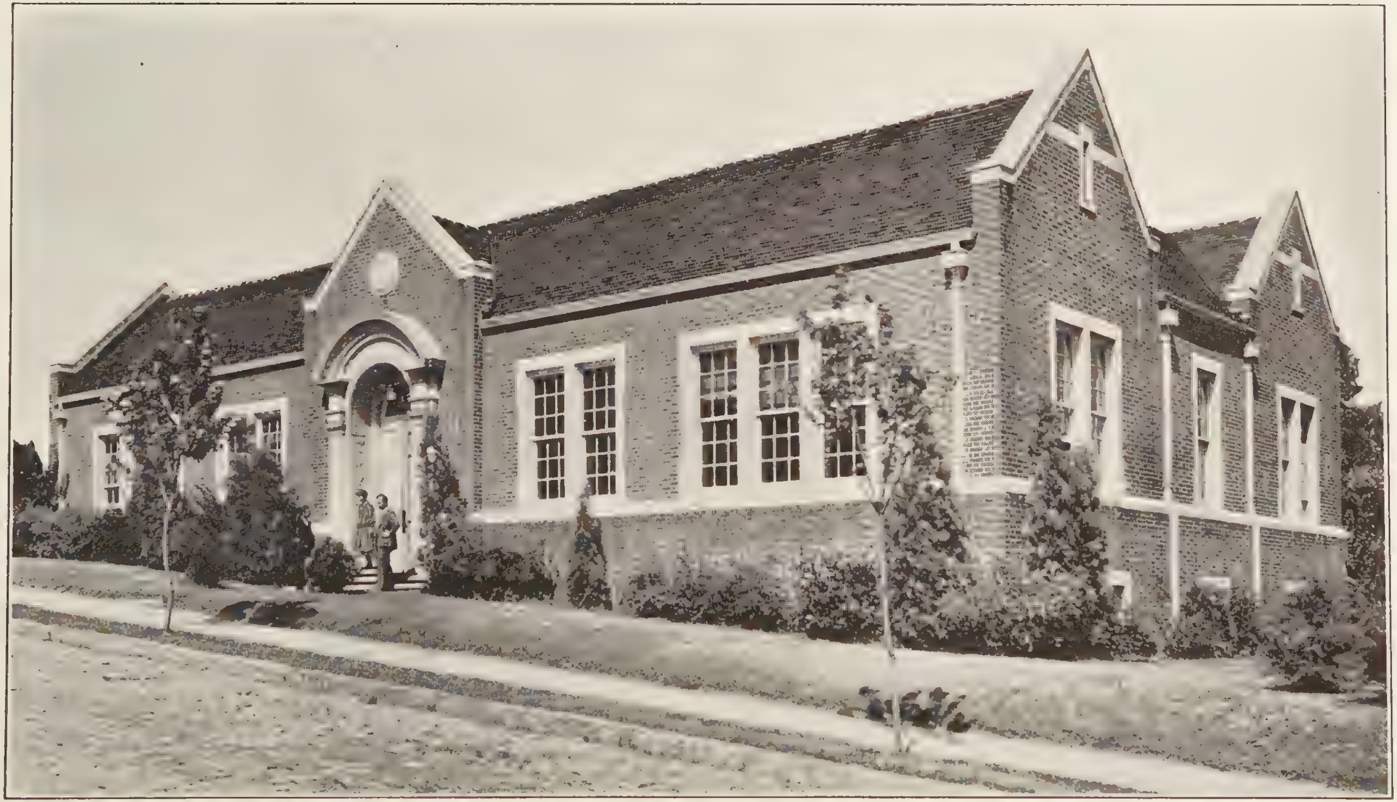

Figure 13.—Ceramics Building, Georgia School of Technology, Atlanta, Georgia. Erected 1924

posits which have been abandoned. The same result would be obtained if efficient methods could be devised for the extraction of aluminum from medium grade ores. Recently the Bureau of Mines issued a bulletin describing the results of research in enriching low-grade bauxite by the flotation process. Partial success was obtained.

The southeastern states are the country's largest producers of fullers' earth and yet the total quantity produced is relatively small compared to that easily available. Fullers' earth in the South is characterized by a high silica to alumina ratio and low specific gravity. It is peculiarly adapted as a clarifying agent for mineral and vegetable oils for which purpose most of the production is used. It appears probable that further chemical research could enlarge the uses of this earth.

Other problems of definite interest to the South are concerned with chemical methods for concentrating cyanite and increased uses of feldspar.

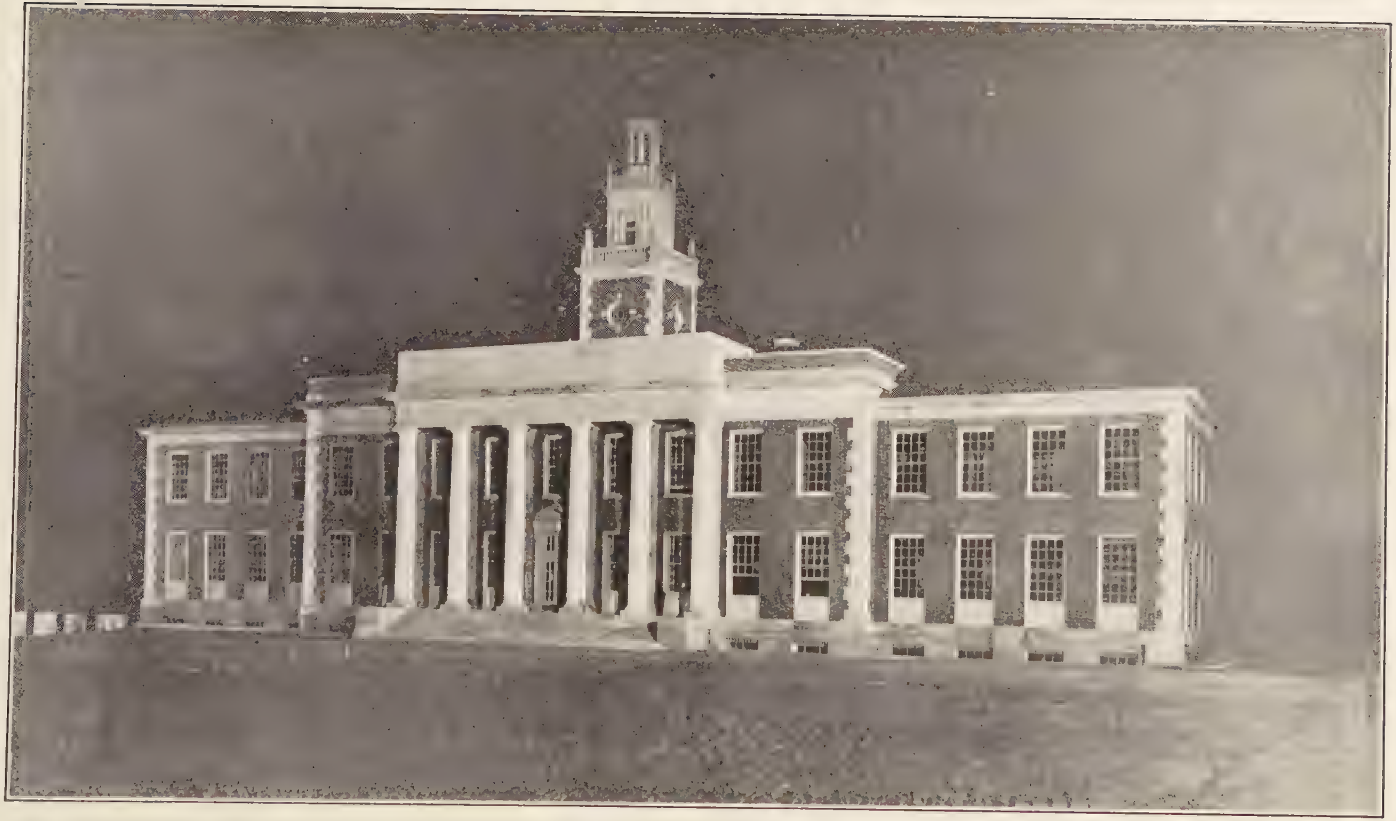

FIGURE 14.—ROSS CHEMICAL LABORATORY, ALABAMA POLYTECHNIC INSTITUTE, AUBURN, ALABAMA. DEDICATED 1930

CHEMICAL PROGRESS IN THE SOUTH

PART III. RECENT DEVELOPMENTS IN CHEMISTRY IN THE SOUTH

PART III

RECENT DEVELOPMENTS IN CHEMISTRY IN THE SOUTH

Foreword

H. E. Howe, Editor, *Industrial and Engineering Chemistry*

Increased chemical activity in the South has followed naturally the diversity of products resulting from an appreciation of natural resources, favorable climatic conditions, and a satisfactory labor supply which characterizes the southern states. The new industries which have sprung up in the South have been those which reach their highest development when chemistry is applied. These are also industries which offer the greatest opportunity for further development, directly in proportion to the emphasis placed upon research by them.

The following discussions, prepared by specialists, afford examples of what chemistry, when given adequate support and opportunity, can accomplish in the southern states. They will also suggest further possible applications resulting in increased employment of labor and capital, with its resultant addition to the wealth of the region.

The recent development of chemistry in the South has not been confined to the mere transplanting of chemical processes developed elsewhere to this virgin industrial soil. New things have been accomplished, examples of which are to be found in the naval stores industry, the electro-chemical industries centering in Anniston, Ala., the progress made in the utilization of various clay and mineral resources, the prospect of better papers from longleaf pine, utilization of the by-products of the cane-sugar industry, and the projects that have accompanied the increasing application of science and technology to natural gas and petroleum.

We have not been accustomed for many years to looking at southern resources through chemical eyes, but now that we have begun to do so, there is reason to expect increased activity. This is not expected to result in mushroom growth and immature development, but rather in those substantial additions to the equipment and productivity of communities which result from careful preliminary surveys, thorough-going research, and adequate tests on semi-commercial scales before full-sized plants are undertaken. This type of work will mean not only close coöperation between existing industries, consulting laboratories, and educational institutions, but the development, near the problem, of facilities represented by reference libraries and adequate research laboratories, which, in the environment of the problem, would seem to be the best method of finding a satisfactory solution with minimum effort and outlay.

CHAPTER XIX

THE RAYON INDUSTRY IN THE SOUTH

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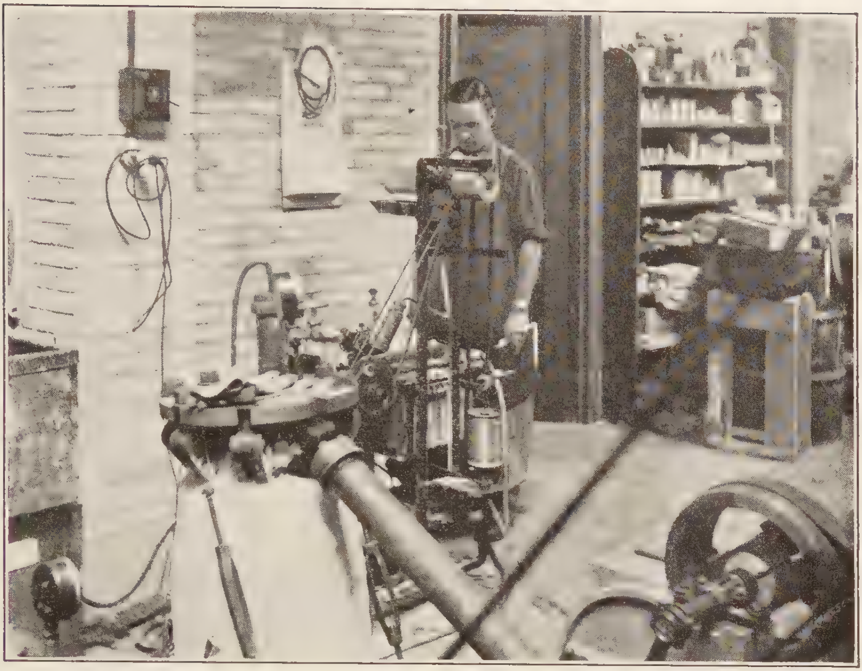
The past decade has witnessed a veritable renaissance in the industrial life of the South, followed by a steady progressive movement, the end of which is not yet in sight. Among the many industries which have been a part of this great forward march, the rayon industry holds a unique position. The necessary expansion of the rayon companies to meet the demand for the product came at a time when the South was experiencing its growing pains. What more natural than that a locality, ripe for industrial expansion and containing the contributing economic factors of raw materials, markets, transportation facilities, power, fuel and water supply, and labor, should attract an industry about to emerge from its chrysalis.

The first plant was built at Roanoke, Virginia, in 1917. From that starting point the industry has developed until, at present, the plants in Virginia, Tennessee, Georgia, and North Carolina have a combined capacity of about 85.5 million pounds annually or about 53 per cent of the United States production. All of the commercial processes for producing rayon are utilized in the various plants of these states.

Manufacturing Processes

Rayon is an entirely new textile material, having a different chemical composition from silk, and an entirely distinct set of physical properties. Natural silk is an animal fiber produced by a large variety of worms as well as spiders. Owing to the fact that the spider web is exceedingly difficult to untangle, it has never been a commercial source for silk production. The culture of silk worms for the production of silk is very difficult but has become very highly developed, especially in Japan. The eggs of the silk worm require from thirteen to twenty days to hatch, and about fifty to fifty-five days elapse before the worm begins spinning its cocoon. During this time the worms consume about one ton of ripe mulberry leaves for every twelve pounds of silk obtained.

The strength, beauty, and softness of silk fabrics induced scientists to search for methods of producing an artificial silk in order to keep pace with the demand. While a true "artificial silk" has never been obtained, these attempts have led to the creation of an entirely new textile fiber—rayon.



Casson

FIGURE 15.—MAKING RAYON, VIRGINIA POLYTECHNIC INSTITUTE

The first commercial success was due to Count Chardonnet. He had been working on some of the diseases of the silk worm and also had considerable experience with gun cotton. He noticed that the cellulose nitrate always had a high luster and that the starting point for natural silk was the same substance, namely, cellulose. Working along these lines Chardonnet produced the first commercially successful rayon in 1880.

In order to get a better understanding of the four processes for producing rayon we should first understand something about cellulose. Every one is familiar with wood alcohol and grain alcohol and, while familiar with glycerin, they may or may not realize that it is also an alcohol. Some of the reactions of glycerin are well known. For example, if we treat glycerin with a mixture of nitric and sulfuric acids we obtain an explosive known as "nitroglycerin." If we use some other acids in place of nitric and sulfuric we can obtain fats and oils. The breaking up of nitroglycerin into glycerin and nitric acid is difficult to control. However, if we boil a fat or an oil with lye we obtain glycerin and a soap.

To the chemist, cellulose, whether obtained from cotton or wood, is an alcohol similar in type to glycerin. If we treat cotton with nitric and sulfuric acids we obtain cellulose nitrate, which is much less dangerous than nitroglycerin. The cellulose nitrate when dissolved in suitable solvents gives us a solution which can be forced through a glass or metal cap containing a number of very fine holes. On removing the solvent we have left the fine, thread-like filaments. If next we remove the nitric acid we have our cellulose in the form of these fine filaments which are twisted together to form our rayon thread. This was the method used by Count Chardonnet and is still known as the Chardonnet or nitro process.

If in place of nitric acid we had treated our cotton with acetic acid we would have obtained cellulose acetate. This is the same substance used in making non-inflammable films for the picture industry. The cellulose acetate is dissolved and spun in much the same way as in the nitro process. The threads produced by the "acetate" process, however, are not changed back into cellulose but remain as cellulose acetate.

A third process, the cuprammonium process, makes use of an ammoniacal solution of copper for dissolving the cellulose. The viscose process uses lye of a special strength and then a compound of carbon and sulfur which converts the cellulose into a soluble compound. In these last two processes the threads are regenerated into cellulose threads.

About 83 per cent of the rayon produced today is manufactured by the viscose process while only about 4 per cent is produced by the nitro process. It is interesting to note that there is only one plant in this country producing nitro rayon. The location of this plant is at Hopewell, Virginia.

Southern Plants

In 1917 the Viscose Corporation built the first unit of their Roanoke, Virginia, plant. This plant has grown steadily ever since and is rated at the present time as the largest single plant in the world. It has an estimated capacity of about 20,000,000 pounds annually and employs about 6000 people.

The Tubize Artificial Silk Corporation of America built its plant at Hopewell, Virginia, in 1921. This company uses the nitro process for the production of rayon. It employs about 3500 people and has an annual capacity of about 12,000,000 pounds.

About 1926 the industry became very active and has shown remarkable expansion since that time. The American Bemberg Corporation at Elizabethton, Tennessee, using the cuprammonium process, started production in 1927, and that same year work was started on the plant of the American Glanzstoff Corporation. This plant is located close to the American Bemberg plant and uses the viscose process.

The next year the du Pont Rayon Company completed the third unit of their first southern plant at Old Hickory, Tennessee.

Last year seems to have been the banner year for this industry as there were no less than six new plants that began production during 1929. These were the du Pont Company's plants at Waynesboro and Richmond, Virginia, the Industrial Rayon Company's plant at Covington, Virginia, the plant of the American Chatillon Company at Rome, Georgia, the A. M. Johnson Rayon Mills at Burlington, North Carolina, and the American Enka Company's plant at Asheville, North Carolina.

Production

The world production for 1930 is estimated at 462,500,000 pounds. Of this amount the United States, the largest single manufacturer, will produce about 35 per cent, or 162,350,000 pounds. In Table I is shown the comparative growth in the production of rayon in the United States since 1926.

TABLE I

Production of Rayon in Million Pounds

Year	*United States*	*World*
1926	62,575	219,080
1927	75,050	266,868
1928	98,650	347,400
1929*	131,325	396,125
1930*	162,350	462,500

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* Estimated.

TABLE II

Estimated Production for 1930 in Million Pounds

		Per cent of U. S. production	*Per cent of world production*
Virginia	44.50	27.50	9.60
Tennessee	27.50	16.90	5.94
Georgia	6.20	3.80	1.34
North Carolina	5.50	3.38	1.09

TABLE III

Company	*Plant location*	*Process*	*Estimated capacity in million pounds*	
Viscose	Roanoke, Va.	Viscose	20.00	
du Pont	Old Hickory, Tenn.	Viscose	15.50	
	Richmond, Va.	Viscose	4.00	
	Waynesboro, Va.	Acetate	2.50	
Tubize-Chatillon	Hopewell, Va.	Nitro	12.00	
	Rome, Ga.	Viscose	4.30	
		Acetate	2.50	
Industrial	Covington, Va.	Viscose	6.00	
Bemberg	Elizabethton, Tenn.	Cupra	4.00	
Glanzstoff	Elizabethton, Tenn.	Viscose	8.00	
Enka	Asheville, N. C.	Viscose	4.50	
A. M. Johnson	Burlington, N. C.	Viscose	14.40	Planned

Table II shows the amount of the United States output which will be produced by the four southern states according to the 1930 estimates. Since 1917 the industry in the South has developed to a production basis of 51.58 per cent of the total United States production and 17.97 per cent of the world production. The locations of the plants, processes, and capacities are given in Table III.

It is of interest to note that about 60 per cent of the United States capacity is under foreign control.

Reasons for Location

It is interesting to analyze the growth of the rayon industry in the South and to determine the various factors which are at work. Possibly one of the greatest influences has been the southern movement of the textile industry in general. Southern mills are now supplying more than 62 per cent of the annual production of cotton goods. These mills are for the most part of the latest modern construction and many of them rank among the largest in their respective branches. The total investment mounts up to over one billion dollars.

During 1929 new mills, new units, enlargements, and improvements in the whole textile industry of the South were as follows: North Carolina and South Carolina, 87 each; Georgia, 26; Alabama, 21; Tennessee, 21; Virginia, 18; Mississippi and Texas, 3 each; Arkansas, 1.

The demand for rayon by the southern mills has constantly increased and while the increase in rayon production has been going steadily forward, the consumption is still some distance ahead as shown by the fact that 16,000,000 pounds of rayon were imported into this country in 1929.

The close connection between the manufacture of rayon and the older textile industry can be realized by a consideration of some of the woven and knitted fabrics. At first rayon was used as a substitute for silk. While rayon, unless delusterized, has a higher luster than silk, it generally lacks the elasticity and strength of the latter, especially when wet. This fact is probably the chief disadvantage of rayon, as great care must be taken not to injure it while wet. When dry it regains its strength.

It found a place first in the hosiery industry and then was taken up by the manufacturers of underwear. From that it gradually spread into other branches of the textile industry, at first being used principally for decorative purposes, then for its own intrinsic value. At the present time rayon is being used alone and in combination with cotton, silk, linen, and wool for the production of all types of knitted and woven fabrics.

Like silk, rayon can be weighted, but the incentive to weight rayon is lacking as it is not as expensive as silk.

In the production of rayon vast amounts of other chemicals are consumed. Cotton linters were used exclusively at first but gradually gave way, to some extent, to a special high-grade sulfite wood pulp. While the amount of cotton linters consumed by the industry still amounts to about 33,000 tons annually, about twice that amount of wood pulp is being used. The amounts of sulfuric acid (50° Bé) and caustic soda are 145,000 and 105,000 tons, respectively. This gives an idea of the necessary development of other chemical industries to keep pace with the expansion going on in the rayon industry. Together with the tremendous growth of the southern market for rayon textiles has gone a corresponding growth in the necessary industries for raw materials. All necessary materials are produced in close proximity to the new rayon plants.

In the South there seems to be abundant labor available with almost none of the radical type. In an industry which is constantly changing and developing as rapidly as this one, labor is an important consideration, especially at the beginning.

The great network of railway systems which covers this section places all the important cities within easy reach of the factories and thus facilitates the movements of raw materials and products.

Future

While the consumption of rayon has increased until it would seem as though the limit must be reached, new uses more than absorb the yearly increase in production. Even last year the imports were greater than they were in 1928 by 4,000,000 pounds. The American Glanzstoff Corporation is at work on the construction of a second unit to its plant which will double its present capacity. The American Enka Corporation, although only starting commercial production during the latter part of 1929, owns a site near Knoxville, Tennessee, which will allow plenty of room for expansion.

The Tubize-Chatillon Corporation plans to increase its capacity for acetate fiber by about 2,250,000 pounds.

It is also expected that before long the du Pont Company will construct another plant in this section.

When these plants are completed, the South will be producing considerably more than 53 per cent of the rayon made in the United States, and, owing to its very favorable climatic, economic, and social conditions, can look forward to an almost unlimited growth in this important industry and its allies.

CHAPTER XX

THE PAPER INDUSTRY IN THE SOUTH

C. E. Curran, Forest Products Laboratory,* Forest Service, U. S. Department of Agriculture, Madison, Wisconsin

The paper industry is far from a newcomer in the South. Virginia had a paper mill as early as 1744 (*1*). North Carolina records show the erection of a mill in Salem in 1766. A decade later one William Bellamy was granted a subsidy of 3000 pounds with which to put up a paper mill in South Carolina. Several mills flourished in Tennessee in the early part of the nineteenth century, and Kentucky boasted a number of paper-making establishments about the same time, although this state has since ceased to be a factor in the paper industry.

After the Civil War there was a considerable development of paper mills in the Virginias and a little later a similar building up of the industry in states farther south. At the beginning of the twentieth century the records show some fourteen mills in the far southern states, although the combined daily output of these mills was relatively small. By 1907, however, a substantial growth both in number of mills and in tonnage was recognized. Lockwood's Directory (*2*) for that year shows some twenty firms operating seventeen paper mills and eleven pulp mills, with combined rated capacities of 85,000 tons of paper and 140,000 tons of pulp a year. A few years later, in 1916, the same authority records twenty-one firms in the same states, operating twenty paper mills and seventeen pulp mills with rated annual production capacities of approximately 200,000 tons each of paper and of pulp.

Following the conclusion of the World War the South shared the general industrial expansion and in 1921 some thirty-two firms were listed as operating thirty-one paper mills and twenty-five pulp plants with an annual production capacity of 280,000 tons of paper or board and 312,000 tons of pulp, respectively.

It is within the past ten years, however, that the greatest progress has been made in the South. The 1930 Lockwood's Directory shows some forty-eight firms operating sixty paper mills and thirty-six pulp mills in eleven southern states. On the basis of 300 working days a year the capacity of these mills is in excess of 1,275,000 tons of paper and 1,110,000 tons of pulp annually. Within a decade, therefore, the pulp and paper interests in the South have increased more than three-fold. Furthermore, there is now much additional activity in the forwarding of pulping projects in the South; a number of new developments are either under way or under advisement.

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* Maintained at Madison, Wis., in coöperation with the University of Wisconsin.

The present status of the pulp and paper industry in the South is shown by states in Table I.

TABLE I

The Pulp and Paper Industry in the South, 1930

State	*Firms*	*Paper mills*	*Pulp mills*	*Daily capacity in tons* *Paper*	*Pulp*
Alabama	3	3	2	310	340
Arkansas	1	1	1	150	175
Georgia	2	2	0	30	120
Louisiana	9	11	7	1429	907
Mississippi	3	3	3	343	350
North Carolina	5	5	5	268	367
South Carolina	2	2	2	80	21
Tennessee	9	6	5	343	433
Virginia	12	15	10	1195	778
Texas	2	2	1	100	35
Total	48	50	36	4248	3526

The remarkable expansion of the pulp and paper industry in the South can be attributed to several factors. The first impetus for it came from the introduction of the so-called kraft or sulfate pulping process and the successful application of this method to the southern yellow pines. The development of the southern industry in the early part of the twentieth century was based upon the pulping of spruce and hemlock from the Appalachian region, although sporadic efforts were made to utilize the gums and other more distinctly southern growths. The first modern mills in Virginia and North Carolina produced soda, sulfite, and groundwood pulps from the Appalachian conifers and hardwoods. Mills in other southern states attempted to compete by producing papers from pines, from various crop plants, or through the repulping of old papers. The difficulties that they encountered resulted in many business fatalities. We find Alabama, Tennessee, and Kentucky, which figured in early papermaking history, more or less disappearing from view for a time and reappearing again only after the technic of pulping southern yellow pine had been perfected. Numerous enterprises in Georgia, Florida, and Louisiana lived a hand-to-mouth existence and in time either disappeared completely or at best struggled along under a balance sheet filled with red figures.

About 1911, however, the Yellow Pine Paper Company, at Orange, Tex., converted their soda pulp mill into a sulfate or kraft mill and within a few years had demonstrated the adaptability of this process to southern yellow pine in the manufacture of kraft wrapping paper and boards. The present southern pulp and paper industry may be said to date from that experiment. By 1916 six kraft mills had been put into operation.

In 1921 this number had increased to nine, while in 1930 the records show seventeen such mills and the present building program in the South is almost entirely for this type of pulp. Perhaps a better way to show the part played by this process in southern pulping expansion is to tabulate the increasing use of southern yellow pine for pulp, as follows:

TABLE II

The Utilization of Southern Yellow Pine for Pulp in the United States from 1920 to 1928

Year	*No. of cords*	*Percentage of total U. S. pulpwood consumption*
1920	323,434	5.3
1922	372,324	6.7
1924	427,961	7.4
1925	531,157	8.7
1926	684,816	10.1
1927	755,175	11.2
1928	925,698	12.9

The quantities of southern yellow pine in Table II easily account for more than half the tonnage from southern mills. These mills used 72,611 cords of gum in 1928.

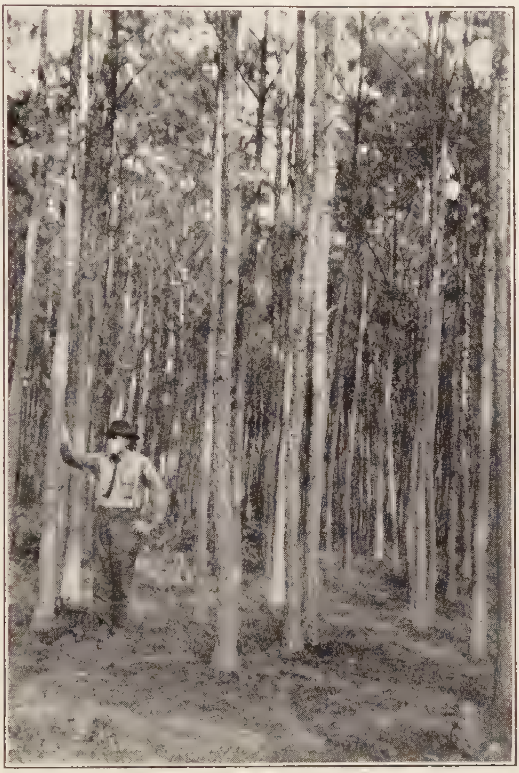
Southern yellow pine constitutes by far the largest forest resource of the South. It reproduces rapidly and, with even moderate precautions in the way of fire protection and forest management, offers a potential supply of low-priced wood in perpetuity. A 20-year cycle has been found adequate for the growing of southern yellow pine of pulpwood size in most of the southern states. An investment in forestry in the South promises to net returns to a pulp mill within the life span of the present management, which is a psychological factor of great value.

Other factors, of course, have played their part in southern pulping progress. The per capita consumption of paper in the United States has increased amazingly in recent years. The southern mills are relatively close to their markets and can easily compete with pulp and paper from the West or from foreign countries. The big advantage, however, is low-cost wood, particularly the southern yellow pines.

The South now produces many grades of paper. Book and writings, tissues, ledgers, and specialty papers of various types are all being manufactured in the Virginias, in North Carolina, and in Tennessee. Soda, sulfite, and mechanical pulp mills are located in these states. The Celotex mills in Louisiana and the Masonite plant in Mississippi are turning out large quantities of insulating and building boards. The newly introduced semi-chemical process is being applied to extracted chestnut chips from the tanning extract plants in the Appalachian area, and to gum in South Carolina. These facts account for the growth of the southern paper industry in departments other than southern yellow pine kraft.

The possible further expansion of the southern industry, however, is dependent upon a wider diversification of products from the southern yellow pines. Undoubtedly, a considerable additional expansion of the southern kraft industry will come. Such favorable factors as low-priced wood, proximity to markets, improvement of transportation facilities, advantages in climatic conditions, and other industrial developments in the South point inevitably toward this. While the specialization on kraft products continues, however, the financial eggs of the greater part of the southern pulp industry are all in one basket. To stabilize, the southern industry must diversify. To diversify it must develop products that can be derived from its one best raw material, namely, southern yellow pine. This is the crux of the present southern pulp problem.

Fortunately, efforts toward such a diversification are already under way. Methods have recently been developed to bleach brown kraft pulps without a serious sacrifice in strength. This product of research offers a possibility of producing strong, light-colored papers that can compete with the products now made almost entirely from northern conifer sulfite. This means also that bleached southern yellow pine pulps may invade the field of paper specialties—a field in which requirements of use set the price, and not the low cost of raw materials or the economy of mass-production methods.



Courtesy of the United States Forest Service

FIGURE 16.—AN EIGHTEEN-YEAR-OLD STAND OF LOBLOLLY PINE IN LOUISIANA

Pines of recent growth seem to be less resinous than trees of older growth, a fact that may prove useful in applying the standard sulfite and mechanical processes of pulping. It matters little that no real progress has yet been reported in this direction; the significance of the fact lies in the implied possibility of producing cheap print papers from southern yellow pines. Such papers form an outlet of large tonnage, and this field has never yet been entered by southern industry.

The possibilities of the South in paper and pulps are of great promise. Progress in recent years in the face of the adverse conditions prevailing in other parts of the country indicates the soundness of the South's economic basis. The potentialities, however, are dependent upon intelligent research and sane developmental progress. Further expansion must be forward-looking and cognizant of the fundamentals basic to continued prosperity, namely, low-cost wood, which means intelligent forest management, and conservation and diversification of products, which will in a measure assure a stabilized operation and lessen the chance of overproduction in any one product.

References

(*1*) Lyman H. Weeks, "History of Paper Making in the United States," New York, Lockwood Trade Journal Co., 1916.

(*2*) "Lockwood's Directory of the Paper and Allied Trades," Lockwood Trade Journal Co., New York.

CHAPTER XXI

NAVAL STORES RESEARCH BRINGS RESULTS*

L. N. BENT, HERCULES POWDER COMPANY, WILMINGTON, DELAWARE

An industry faced with overproduction and a limited market for its products has two alternatives if it desires to correct the situation without waiting for the ultimate economic solution, which is "survival of the fittest."

One alternative is the purely artificial and difficult method of curtailing production to meet the demand, which can be accomplished only if the industry is controlled by a limited number of interests or with governmental aid. This policy is sound only if the restriction of output will in the long run result in conservation of natural resources to meet the normally increasing demands of a growing population.

The other alternative is actually to increase the demand for the products of the industry and to create new products for which there is already an established demand. This can only be accomplished through research. Research is expensive and sometimes slow in getting results; but any industry, the development of which is based on the right kind of research, will eventually find itself in a position to meet any economic condition without disaster.

The naval stores industry for years has been suffering from overproduction and a limited outlet for its products. This condition has given rise to many kinds of speculative and artificial trade practices which have been responsible for direct loss to producer and consumer alike.

This condition has been generally recognized and much discussion has taken place in an attempt to arrive at some solution of the problem. Curtailment of production has been proposed and various schemes have been suggested whereby this could be accomplished. Concerted advertising has been suggested and research through the Pine Institute of America has been started.

In view of the general interest in the present and future problems of our industry, it may be timely and of interest to outline briefly the endeavors and accomplishments of the Hercules Powder Company since its advent into the naval stores industry about ten years ago.

The Hercules Powder Company confined itself entirely to the production and sale of naval stores produced from wood by the steam and solvent process and very soon realized that a very limited demand existed for the products made in this way. Production capacity far exceeded the market, costs were high, and a very decided prejudice was held by the consumer against wood rosin and wood turpentine.

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* Reprinted from *American Paint Journal,* September 2, 1929.

To meet this situation a very definite policy was decided upon: first, to cut production commensurate with sales, and then to embark upon an extensive research program having as its object improvement of process and quality of products and the development of new markets and new products which could be sold.

Following this program, one of our plants was immediately shut down and later abandoned, and the other plants were operated at reduced capacity. Research laboratories were established in the South and in the North. The southern laboratories were designed to work on improvements in process and products and the northern laboratories were to work out the more fundamental chemical problems requiring special and intricate laboratory apparatus and to establish and maintain contacts with other industries.

It was recognized very early in this work that very little real progress could be made unless we knew more about the materials with which we were dealing. Nobody knew exactly what rosin was and what impurities in rosin caused different results when used in different industries. Pine oil and its constituents were more or less of a mystery, and the constituents of turpentine and their properties were little understood. Much time has been spent in purely fundamental research with the idea that, once having real facts to work on, development of new products would be much more rapid.

Our laboratories in the South instituted strict chemical control of operations, with the result that the cost of manufacture was materially reduced and finished products, uniform in character, were consistently turned out.

Consumer's Needs Must Be Met

It is useless to make products for sale unless they meet the requirements of the consumer, both from the standpoint of quality and cost. To get the viewpoint of the consumer, we established a so-called Technical Service Department made up of highly trained chemists and engineers, each possessing special knowledge of some basic industry consuming naval stores. This department serves as the contact between consumer and research laboratory and between consumer and production department. Knowing both consumers' requirements and conditions and the possibilities of our plants and laboratories, it is largely responsible for ideas from which new and useful products originate. Besides this, the members of the Technical Service Department have many times been able, out of their experience, to show customers how to use our products more economically or perhaps how to replace some other product with a naval stores product to advantage. The work of our Technical Service Department is market research of a very practical and necessary character.

Typical of the economies resulting from Hercules men working closely with the consumer is the shipment of rosin in tank cars with its consequent saving in package, freight, and handling; the manufacture of special kinds of limed rosin designed to save the consumer the cost of an added operation, but accomplished at our plants without extra cost; and many other special grades of rosin made to meet conditions where solubility, melting points, and freedom from crystallization are necessary.

Years Required for Research

Work of our research laboratories is so basic in its character that many years must elapse before its real value to the industry will be completely apparent. However, already much of commercial importance has been accomplished and mention of the more outstanding developments will perhaps be interesting.

The most important development from the standpoint of the steam and solvent industry is undoubtedly the production of refined wood rosins. These rosins make possible and desirable the use of wood rosin in all classes of industry using rosin. These new rosins are enabling consumers to produce superior products at lower cost. They have been made possible by chemists working in Hercules laboratories, and the products and processes have been patented.

Varnish and Lacquer Materials

"B" wood rosin is a new naval stores product. It is a low-cost material, but with unique properties; and is attracting the attention of many industries, some of which have never used any kind of rosin before.

Rosin esters, prepared from practically every available alcohol, are now available, making it possible for the naval stores industry to find an outlet for some of its products in the rapidly expanding lacquer and thermoplastic industry. These processes were developed by Hercules chemists and many of the products are patented.

Research has made naval stores of particular interest to gloss oil and varnish manufacturers. By a low-temperature method of liming rosin, it has been possible to procure greater capacity from existing installations, decreased fire hazard, and a better quality of finished product.

In the turpentine field great progress has been made. Steam-distilled turpentine has been developed to a point where it is now superior to most other turpentine on the market. This has been accomplished by eliminating heavy end or high-boiling constituents which cause slow drying or tackiness, and by elimination of aldehydes and other foreign bodies.

New Developments

An entirely new chemical with distinctly valuable properties has been added to the naval stores industry with the development of dipentene. This product was first put on the market by Hercules in the form of solvenol. Its ultimate possibilities are as yet far from being realized.

Terpene chemicals, heretofore known mostly as chemical curiosities, are now available in commercial quantities at reasonable prices. These include fenchyl alcohol, fenchone, alpha terpineol, borneol, and other terpenes and terpene alcohols. These products, or their esters or other derivatives, are interesting on account of their high molecular properties. They may serve as the starting point in the manufacturing of an almost endless number of other chemicals.

Polymerized and condensation products, as well as hydrogenated and ozonized terpenes, are other terpene chemicals which possess very interesting characteristics and should occupy an important place in the industrial world.

Unlimited Possibilities

Other special products have also been produced in our research laboratories and are now being tested to determine their properties and possibilities. These developments have been conducted on the basis of rosin, turpentine, and pine oil being potentially valuable organic chemicals whose derivatives offer almost unlimited practical application.

It will be noted that many of the products and processes discovered in Hercules laboratories are covered by patents. This is a practical and necessary culmination of research work, whether conducted by an individual producer or by a united industry. Protection by patents implies monopoly; but such monopoly properly administered means stabilization and progress to the whole industry, at the same time benefiting the consumer, without imposing a penalty on those whose expenditure of time and money has made such progress possible.

Looking back over the past few years, we believe some real progress can be shown resulting from our advertising, technical service, and research work. The terms "wood," as applied to rosin, and "steam-distilled," as applied to turpentine, no longer indicate inferiority to the customer; on the contrary, they now indicate reliable, uniform raw materials, especially adapted to meet the varying requirements of the consuming industries.

How Individual Effort Benefits Industry

Our work, of course, has been primarily to increase the demand for Hercules products and to enable us to meet this demand in the face of increasing and destructive competition. However, the results of our work will, undoubtedly, be of value to the naval stores industry as a whole; and rosin and turpentine producers are bound to share in the new markets for our products which are continually being developed as a result of our research work.

CHAPTER XXII

THE SWANN CORPORATION

C. H. PENNING, SWANN RESEARCH, INC., BIRMINGHAM, ALABAMA

The Swann Corporation, with headquarters at Birmingham, Alabama, as organized today represents one of the most interesting developments in chemistry in the entire South.

This organization originated during the World War with the formation of the Southern Manganese Corporation, making ferromanganese by the electric furnace process in a plant erected at Anniston, Alabama. Ferrosilicon was also made at this plant until the armistice was signed, at which time the price of ferromanganese dropped so that its manufacture in the electric furnace became unprofitable. The production of ferrosilicon and ferrochrome was continued for about a year longer.

Early in 1918 the War Department approached Mr. Swann, president of the Southern Manganese Corporation, with a request for a supply of elemental phosphorus, and the Federal Phosphorus Company was incorporated on July 23, 1918. No phosphorus was ever produced for sale.

Numerous attempts were made to convert the electric furnaces to other products having a profitable market. Ferrophosphorus was among the ferro-alloys tried. A logical development of this was the recovery of phosphoric acid from the fumes evolved from the furnaces, using Cottrell precipitators. The acid produced in this manner is of high strength and exceptional purity as compared with other commercial grades. Since it is water-white and conforms with the Government pure food laws, much of it is consumed in making products of food grade. Ferrophosphorus, made in two grades (18% P, 25% P), is used for rephosphorizing steel.

With the acid as a basis, the manufacture of phosphoric acid salts was developed gradually, and the following products are now being made—mono-, di-, and tri-sodium phosphate, mono- and di-ammonium phosphate, mono- and tri-calcium phosphate, acid pyrosodium phosphate, and phosphoric acid paste. Of these the largest is tri-sodium phosphate, over 30,000,000 pounds being made annually for use in water softening, in boiler compounds, and as a general cleanser.

Low-cost electric power being available for certain periods of the year, it was decided in 1924 to go into the manufacture of other materials requiring considerable power. The Federal Carbide Company was incorporated on December 6, 1924, and the Federal Abrasives Company on December 30, 1924. Production of calcium carbide, aluminum oxide abrasives, and silicon carbide by these companies was started in 1925 and has been continued since that time.

In 1925 it was considered advisable to have available another source of power supply which could be relied upon in case of shortage of supply from the present source. A survey of available sites was made, and in that year the Federal Power Company, the Federal Power Company of Tennessee, and the Hiwassee Power Company were incorporated, to own and control purchases of land for these power sites. It is estimated that approximately 275,000 horsepower is available at the sites purchased, these constituting some of the largest undeveloped hydro-electric power sites in that section of the country.

Additional land was also purchased at Anniston, making the holdings at the plant site approximately 640 acres.

In 1923 the Federal Phosphorus Company took over the management of the Provident Chemical Works at St. Louis, Mo., which has since become the third largest manufacturer of mono-calcium phosphate in this country, and in 1929 an interest was purchased in the Iliff-Bruff Chemical Company of Hoopeston, Ill., manufacturers of mono- and tri-calcium phosphate. With the acquisition of these various interests, a central organization or holding company was necessary, and accordingly the Federal Electro-Chemical Company was incorporated in Delaware, December 28, 1925. The name of this holding company was changed in 1929 to The Swann Corporation, taking the name of the president, Theodore Swann. On June 1, 1930, the various operating companies at Anniston, with the exception of the Federal Abrasives Company, were consolidated under the name of the Swann Chemical Company.

The story of the development by this organization of the manufacture of diphenyl and its derivatives is being told in another article, as is also the story of the coöperative work on the production of xylose from cottonseed hull bran carried on in conjunction with the Bureau of Standards, the University of Alabama, and the Alabama Polytechnic Institute. These two operations differ radically from the other business of the company, and are evidence of the wide vision of the directing heads of the corporation.

A still more recent development is the establishment of a textile chemical division for the manufacture of the staple chemicals now used in the textile industry and for the production of new and improved compounds which will better serve the industry. Among the new products already developed may be mentioned a series of special oils for rayon processing and a new wetting agent of considerable promise. The rapid growth of the textile industry in the South fully justifies the establishment of a reliable source of chemical supplies located in its midst.

All of the products mentioned are the result of a great amount of study and experimentation. Substantially every process or product of The Swann Corporation has been developed within the organization. Such competitive products as are made are mostly those whose manufacturing processes were secret or the details not available. With others, because of a freight disadvantage in the principal markets, sales resistance had to be met by a superior product. One of the fundamental principles on which The Swann Corporation operates is the manufacture and sale of quality products only. Possibly the greatest mistake in southern industrial development has been the general inclination to market products in a crude or mediocre state, selling the lowest grade which would find a market. The Swann Corporation has proved that business is fundamentally on a sounder basis when a superior quality of product is made.

Recently (January, 1930), the research activities of the corporation have been coördinated and unified with the incorporation of Swann Research, Inc., which will operate as a separate business. As new products or processes are developed they will be assigned to the operating companies on a royalty basis. The royalties paid will provide the research organization with an income commensurate with its own productivity, thus giving a measure of its value. Its permanence is assured as long as it continues to produce. If, through incompetent effort, practical results are not forthcoming after a reasonable period, its scale of operation will be automatically curtailed.

Swann Research, Inc., is divided into three departments—Commercial Research, Chemical Research, and Plant Development. The Commercial Research Department handles market surveys and economic investigations of proposed products and processes, and finds markets for new products developed by the laboratories. The Chemical Research Department conducts laboratory research on such products and processes as have been favorably reported by the Commercial Research Department, and is constantly engaged in work on the improvement of present methods and materials and the discovery of new products, adaptations and uses. After the laboratories have completed their fundamental work, the Development Department takes the problem through pilot-plant operation to large-scale operation. Careful coördination and coöperation of all three departments is necessary to keep the work on a sound basis.

This brief recitation of the history and present activities of one southern chemical company, considered in connection with the rapid industrial development of the South in other lines of enterprise, and keeping in mind the vast natural resources of the region which are just beginning to be tapped, gives a general picture of the extent and rapidity of the South's material progress in recent years and a vision of what the future holds for this section.

CHAPTER XXIII

DIPHENYL AND DIPHENYL DERIVATIVES

C. H. PENNING, SWANN RESEARCH, INC., BIRMINGHAM, ALABAMA

In November, 1927, The Federal Phosphorus Company of Birmingham, Alabama, was asked to attempt to develop a process for the manufacture of diphenyl ($C_6H_5.C_6H_5$) on a commercial scale at a price that would make possible its use as an indirect heating medium. At that time diphenyl was a rare chemical, quoted at $8.00 for 100 grams, or about $36.00 a pound. An intensified research and development program was immediately launched, and within four months a process was devised, a plant designed and put into operation and one carload of diphenyl produced. Thirty days from that time the first plant had been completely dismantled and a second plant, designed and constructed on a new principle, was producing diphenyl at the rate of approximately three thousand pounds a day. At this time the price of diphenyl was set at forty cents a pound in carload quantities, or one-one-hundredth of the price paid for it less than six months before. Since that time another new plant has been constructed and the present quotation for technical diphenyl, 99.5% pure, is thirty cents a pound in carload lots.

Diphenyl as an Indirect Heating Medium

As an indirect heating medium diphenyl holds considerable promise because of its high boiling point and low vapor pressure at elevated temperatures. Its advantages in connection with various evaporation, distillation, digestion, drying, and other operations involved in the oil, chemical, soap, paint and varnish, enameling, and many other industries where high temperatures are required are now being actively investigated. Diphenyl will also be found to offer advantages as a medium for reheating steam in electric power stations, thereby eliminating the necessity for the presently employed reheat boiler.

Commercial diphenyl, as manufactured by The Federal Phosphorus Company, has a melting point of 68.7°C., a boiling point of 255°C., and a critical temperature of 527°C. It is known to be stable at 450°C., and it has recently been reported that a diphenyl boiler has operated at 480°C. for five hundred hours with no evidence of decomposition or attack on the metal (steel and cast iron) used in the construction of the equipment. Tests are now under way to determine accurately its limiting temperature.

In using diphenyl as an indirect heating medium it will be handled much in the same way that steam is used for the same purpose, the primary differences being that certain additional precautions are necessary. Particular attention should be paid to getting the system absolutely tight in order to prevent leakage and the consequent necessity of make-up. Welded joints are recommended. The boiler should be of the forced circulation type in which only a portion of the diphenyl is flashed on each passage through the tubes. Hot spots in the furnace and dead spots in the tubes should be avoided in order to eliminate possibility of decomposition of the material. The circulation pump should be one of the several standard designs that have water-cooled stuffing boxes, and particular attention should be paid to the pump capacity, because of the rapid change in the density of liquid diphenyl with change in temperature. When designing the system it should be kept in mind that diphenyl solidifies at 68.5°C. and it is therefore necessary to provide some outside means for warming up the system when starting operation. The possible excessive expansion of metals at the temperatures employed should also be borne in mind.

Analogs of Diphenyl

As a result of further research and development work on the pyrolytic process employed for the manufacture of diphenyl, a number of other analogous products are being made. Typical of these are the isomeric phenyldiphenyls, with boiling points more than 100° higher than that of diphenyl itself. The commercial possibilities of these products rank with those of diphenyl.

Diphenyl Derivatives

The availability of diphenyl in large quantity at a comparatively low price has stimulated research on the production of a wide range of derivatives. The analogy between diphenyl and benzene suggests the manufacture of new compounds in which diphenyl is substituted for a single benzene ring; the possibilities are very great, when one considers the number and variety of compounds containing benzene rings. Another suggestion is the substitution of diphenyl for naphthalene in naphthalene derivatives—a most interesting study. Work along these lines and others is progressing in a large number of research laboratories in this country and abroad.

At the plant of The Federal Phosphorus Company at Anniston, Alabama, the simpler derivatives of diphenyl are being made on a commercial scale. These include the chlorinated compounds, nitrodiphenyls, aminodiphenyls, and diphenylsulfonic acids. The associated laboratories of Swann Research, Inc., are working with other derivatives, developing methods for large-scale production as demand arises for the products.

Of the commercial materials, the chlorinated products appear at present to have the widest application. The pure monochloro derivatives are crystals when separated into the two isomeric forms, but when mixed in certain proportions they form a eutectic melting at 14°C., boiling around 275°, and having a viscosity close to that of water. By further chlorination, under special control, the viscosity may be increased; the resulting products vary in consistency from that of the product described above to that of a thick sirup, a gummy or resinous product, or a solid crystalline resin. Products of any desired viscosity between these limits may be obtained.

The melting and boiling ranges of these products rise with the viscosity, as does the specific gravity. All of the products are stable on prolonged heating at 150°C.; they have no noticeable action upon the skin. The lower-chlorinated products have a distinctive, though not unpleasant, odor; the more highly chlorinated bodies are practically odorless and tasteless as well. In color they range from water-white to light amber. The liquids are non-drying and undergo no apparent oxidation or hardening on exposure to air. Similarly the gums and resins are thermoplastic; they undergo no further condensation or hardening on repeated heating and cooling. All are insoluble in water but soluble in practically all of the ordinary organic solvents and mineral and vegetable oils.

The proposed commercial applications for these materials are as varied in nature as are the products themselves. The pure mono- and di-chloro isomers are starting points for other more complicated derivatives, some of these latter products already made appearing of interest as intermediates for dyes. The other chlorinated bodies, mixtures of various isomers of varying degrees of chlorination, are being marketed under the trade name Aroclor, and, in addition to having the usual possibilities of high-boiling organic liquids, gums and resins, have special applications for waterproofing, flame-retarding, and electrical uses because of their inherent physical characteristics.

The other primary derivatives of diphenyl, while not yet so fully investigated as the chloro compounds, likewise give promise of profitable commercial application. Thus, the solution of what originally appeared as a problem involving the production of a compound of probably limited, application has resulted in a development of a very wide scope which may ultimately have a marked effect upon some of our largest industries.

CHAPTER XXIV

THE MANUFACTURE OF COMMERCIAL ANHYDROUS ALUMINUM CHLORIDE*

A. M. McAfee, Gulf Refining Company, Port Arthur, Texas

In 1915, at the San Francisco meeting of the American Institute of Chemical Engineers, the author presented a paper on the "Improvement of High-Boiling Petroleum Oils and the Manufacture of Gasoline as a By-Product Therefrom by the Action of Aluminum Chloride" (*1*). In that paper it was indicated that further papers might be forthcoming. That was fourteen years ago. That was also the beginning of litigation which has run the gamut from the interference proceedings in the Patent Office and federal courts to suits for title in state and federal courts, finally culminating in the Supreme Court, which a few months ago rang down the curtain on the proceedings. While this litigation was in progress the writer did not feel that it was proper to discuss publicly the subject of aluminum chloride.

These years not only have been full of litigation but have also been full of developments covering the large-scale manufacture and uses of aluminum chloride by Gulf Refining Company. It is the purpose of this paper to discuss the manufacture of commercial anhydrous aluminum chloride and to give some details of Gulf Refining Company's method of manufacturing this interesting chemical in quantities and at a cost which ranks it among the heavy chemicals of commerce, such as caustic soda.

Aluminum Chloride Made Commercially Available

In the year 1913 the writer purchased a few pounds of aluminum chloride for $1.50 per pound. It required six weeks to get it. Today Gulf Refining Company is manufacturing aluminum chloride at Port Arthur, Texas, from bauxite ore and chlorine at the rate of 75,000 pounds per day and at a cost such that it can be purchased in carload lots at five cents per pound.

It is amusing to read the remarks about the high cost of aluminum chloride which nearly always accompany the published references to its uses. They say it will do this and do that, but the usual "but" is that it is too expensive. The lowest figure that the writer has seen published is fifteen cents per pound and that seemed to be a wish rather than a reality. Within the past few months an article (*2*) has been published in which the statement is made that all the anthraquinone manufactured in this country is being made synthetically by means of aluminum chloride, but the process is handicapped by the high cost of aluminum chloride and the difficulty of handling it. It is hoped that the present paper will effectually dispose of the first objection as to cost, and in regard to handling it should be pointed out that Gulf Refining Company has made and consumed thousands of tons at its Port Arthur refinery and has shipped hundreds of tons in iron drums by rail to its Fort Worth refinery without difficulty.

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Baeyer's statement long ago that the story of the uses of aluminum chloride sounds like a fairy tale, is true. Elbs' "*Synthetischen Darstellungs Methoden*," Volume 2, published in 1891, devotes 45 pages to aluminum chloride in the Friedel and Crafts syntheses of hydrocarbons, ketones, acid amides, phenols, etc. Meyer and Jacobsen, 1902 edition, contains one hundred and seventy-eight references to various applications of aluminum chloride in synthetic organic chemistry. Its possibilities in commercial organic syntheses have long been recognized, but little progress commercially has been made heretofore, on account of the high cost and inadequate supply. Not until recent years has there been a determined and successful effort to make aluminum chloride cheaply and in large quantities. To Gulf Refining Company goes the credit of having first tackled and solved this problem. Here, again, necessity was the mother of invention. Gulf Refining Company was in possession of a process for making gasoline from higher boiling hydrocarbons and of a process for refining petroleum oils in general, and lubricating oils in particular, by means of this remarkable chemical. The possibilities of these inventions were alluring, but they were indeed fairy stories until aluminum chloride could be made from basic raw materials (not metallic aluminum) at a reasonable cost and in thousands of tons. Gulf Refining Company is so making and using it now for these purposes and doubtless will continue to do so.

Development of Process

Its first attempt to make aluminum chloride in a large way was started in 1915. There was, of course, no precedent to which to turn for help. The only alternative was to make the best guess possible and let Gulf Refining Company foot the bills, which it generously did for several long, lean years. The first apparatus consisted of vertical fire-clay retorts about twenty-four inches inside diameter by twenty feet in height. These were heated from the outside. The fire-clay tile cracked from top to bottom. No aluminum chloride was made except when metallic aluminum was used which, of course, was out of the question. Cost—six months' time and thousands of dollars. Then circle fire-brick were substituted for the fire-clay tile. This was an improvement inasmuch as the fire-brick did not crack under the heat of 1600°F. but, as is well known, chlorine is a lively agent at ordinary earthly temperatures; heat it to 1600°F. and it eats brick. This was too expensive to be considered. Cost—another six months and another several thousand dollars. For trial number three the best ceramic experts whom the country afforded were consulted. Retorts of porcelain were built with ground joints fired with outside producer gas to keep down hot spots. But chlorine at 1600°F. in the presence of carbon devours porcelain quite as readily as fire-brick. An attempt was made to produce aluminum chloride by applying the necessary heat through retort walls to bauxite and carbon and chlorine. Where the heat should be greatest it was least; and where it was most intense, heat was not desired—that is, along the retort walls. At these temperatures it takes chlorine a surprisingly short time to eat a hole in a retort wall and that hole does not get smaller.

The records show that approximately two years and one million dollars were spent trying to make aluminum choride from bauxite ore in a large way without bringing the cost of production to reasonable figures. It was realized that there were substantial reasons why this chemical had never been made in large amounts and why its cost was so often mentioned as making it prohibitive in the arts.

But this time and money were not spent in vain. Many important details as to how to do it and how not to do it were learned. There were several more years of development work, but these years of effort did not give negative results. Each successive step proved to be in the right direction, until today the process is one of extreme simplicity.

Details of Present Process

The present process, which has been operating successfully for several years, is as follows:

The crude bauxite ore, which should be reasonably low in silica and iron, is calcined in an internally heated rotary kiln at about 1800°F. to drive off the free and combined moisture which usually amounts to about 40 per cent of the ore. From the kiln, the bauxite is delivered by belt conveyor and bucket elevator to a weighing hopper where a good coking coal is added in the proportion by weight of approximately three parts of bauxite to one of coal. The mixture of bauxite and coal is then put through a pulverizer where the two solids are ground to a powder. From here it is directed to overhead hoppers, which feed into mixing vats to which is delivered a liquid binder, such as wax tailings or melted asphalt. The mixers discharge automatically into briquetting machines, which press the bauxite, coal, and binder into briquets under a pressure of three thousand pounds per square inch. Each briquet weighs approximately two pounds. Before chlorinating, all hydrocarbons, as well as moisture, must be driven out of the charge; otherwise there will be a waste of chlorine as hydrogen chloride. Hence, the briquets are preheated to approximately 1500°F., thus driving out the volatile matter in the coal and leaving a hard briquet composed of approximately 82 per cent bauxite and 18 per cent carbon. The hot carbonized briquets are then charged to the chlorinating furnaces.

The largest chlorinating furnace which Gulf Refining Company has thus far built has a capacity of forty thousand pounds of aluminum chloride per day. It has an inside diameter of five feet and the shaft is twenty feet in height. The shaft consists of two courses of circular fire-brick and behind these is a layer of powdered bauxite incased by an iron jacket. The object of the powdered bauxite is to protect the iron against chlorine. Near the top of the shaft are inlets for chlorine, and near the bottom is an outlet for aluminum chloride connected to condensers. This size of furnace takes about twenty tons of carbonized briquets at a charge. They are introduced through an opening at the top of the shaft. A blast of air is then introduced at a point near the bottom and halfway up the shaft for about fifteen minutes, at the end of which time the charge of briquets will have been heated to the desired chlorinating temperature of about 1600°F. The top door is then closed and chlorine turned in for a period of from eight to ten hours, when it becomes necessary to replenish the charge of briquets and restore heat. With smaller sizes of chlorinating furnaces it is necessary to recharge and restore heat more frequently. Thus the operation proceeds in any particular furnace until the fire-brick lining must be renewed. Under present operating practice a lining is good for about one hundred days.

Impurities in Commercial Product

Having in mind that all of the constituents of bauxite are converted into volatile chlorides, the quality of the aluminum chloride produced obviously depends upon the quality of the bauxite used. The analysis of bauxite is generally given on the dried basis, and that is what has been used in the following discussion. A bauxite containing not less than 57.5 per cent alumina is considered to be good quality in respect to its alumina content. Aside from fractional amounts of alkali and alkaline earth elements, and perhaps rare earth elements, the remaining constituents of bauxite are combined moisture and the oxides of silicon, titanium, and iron. In the Arkansas and South American bauxites, the combined moisture and titania content vary only slightly, usually 29 to 31 per cent and 2 to 3 per cent, respectively. Silica and ferric oxide are the variables to be watched. The presence of silica means the loss of chlorine as silicon tetrachloride, and the more iron there is in the ore the more ferric chloride in the aluminum chloride. It is preferable to use a bauxite containing less than 5 per cent silica and 3 per cent iron oxide. With these constituents fixed at a maximum figure, the alumina content takes care of itself. There is an abundance of bauxite available in South America and considerable in Arkansas running much lower than 5 and 3 per cent of silica and iron oxide, respectively. The ore now in use, and which has been used for some time, produces commercial aluminum chloride containing not less than 94 per cent aluminum chloride, the remainder being varying percentages of the chlorides of iron, titanium, and silicon, in amounts diminishing in the order named.

Development of Condensers for Aluminum Chloride

A few words might be said about aluminum chloride condensers. This equipment also went through a development stage with plenty of grief. If you have ever had occasion to prepare aluminum chloride in the laboratory, you probably followed Gattermann's directions, which describe at some length how to avoid stoppage of the apparatus by aluminum chloride condensing where it is not wanted. Doubtless you were impressed with the importance of observing his precautions. As you know, aluminum chloride passes from the vapor to the solid phase, under substantially atmospheric pressure, without going through the liquid phase. It condenses quickly and is a very effective stopper.

Another problem was what material should be used for large-scale condensing; and another, what design. In the early days a modest-sized brick condenser with staggered baffles was used. This was connected as closely as possible to the chlorinating furnace. The aluminum chloride had to be discharged by hand. This did fairly well for that scale of operation, but when it came to larger production the manual labor required to remove the chemical was found to be prohibitive. Another item which did not show up in the smaller condensers was even more serious. Carbon monoxide is one of the gaseous products of the reaction. The brick condensers used at that time were about thirty feet long, twelve feet high, and six feet wide. This provided space for the accumulation of sufficient carbon monoxide which, when mixed with air as would often occur, resulted in an explosion which at times would wreck the whole condenser. Many of the present employees of the Gulf Refining Company have been with the process from the beginning of large-scale work. They have many stories to tell, but none more amusing than their experiences with these condensers. Today all the aluminum chloride is condensed in sixteen-inch iron pipes placed vertically. Revolving shafts and blades inside the pipes knock the aluminum chloride into hoppers as fast as condensed. The result is that the chemical is deposited in hoppers in the form of a powder, 75 per cent or more passing a ten-mesh screen. This fineness permits drawing the aluminum chloride through a sliding door into iron drums or other convenient receptacles. If aluminum chloride is permitted to condense and solidify undisturbed, as was the case with the old brick condensers, it builds up into a solid rock-like mass, ultimately plugging the condenser no matter what the size. Aluminum chloride has been known to spud out of the brick condensers in chunks weighing several hundred pounds each. Aside from labor saving, the advantages of the present condensers over the old type can readily be appreciated. The life of an iron pipe condenser such as is here described is at least two years. This is surprising since there is always some hydrogen chloride and often a trace of free chlorine in the condensers, particularly if the charge of briquets is allowed to become too low. The reason for this long life is that the inside pipe walls become coated with a thin layer of aluminum chloride, which protects the iron from corrosion. Another item which adds to the longevity is the cooler, located between the chlorinating furnace and pipe condensers. Its object is to cool the aluminum chloride vapors to a temperature somewhat above their condensing temperature, thus increasing the capacity of the pipe condensers and minimizing the action of corrosive gases. This cooler is generally lined with a single course of firebrick. It also acts as a trap for any bauxite or carbon coming from the chlorinating furnace.

Further Improvements Promised

Recent improvement in the manufacture of aluminum chloride by the Gulf Refining Company indicates the passing of the necessity for briquetting, substitutes refinery coke for coal, eliminates blasting the chlorinating furnace with air to restore heat, and seems to permit the enlargement of the furnaces to the size of, say, an iron blast furnace. Further, the charge of bauxite and coke is so distributed that practically no chlorine comes in contact with the shaft lining, thereby eliminating entirely the trouble to which reference has been made at some length in this paper. These facts have been established by experimental work on a large scale, and the plant is now being converted to this system. Further details regarding it can well form the subject of a future paper.

It will be the policy of the Gulf organization to make aluminum chloride available to the public for all uses as freely as possible in excess of Gulf's requirements and subject to royalty when used in its patented process and apparatus for converting and refining petroleum and its products. It is their expectation that the present price of five cents per pound will shortly be lowered to even more attractive figures.

Acknowledgment

This development has not been a one-man job. It has required the combined efforts of many men pulling together, all of whom are now, or at some period have been, a part of the Gulf organization. Some may have spent more days and nights on the problems in the early years of development and, as a consequence, may have come into contact with more grief, but that does not matter now.

It seems fitting to mention one in particular whose personality and leadership inspired others to overcome difficulties which many times seemed insurmountable—namely, George H. Taber, formerly vice-president of Gulf Refining Company, who retired on December 31st last, after fifty-two years of notable service in the petroleum industry.

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(*2*) Jaeger, *Ibid.,* **20,** 1330 (1928).

CHAPTER XXV

ALUMINUM IN THE SOUTH

J. D. PORTER, ALUMINUM COMPANY OF AMERICA, PITTSBURGH, PENNSYLVANIA

The importance of the South to the aluminum industry is two-fold: (1) abundant water power means cheap electricity, which, to the economical production of aluminum, is a fundamental necessity; (2) the new growth of industry in the South furnishes new markets close to aluminum production centers. The validity of this second consideration is attested by the fact that whereas hydroelectric power accounts only for the production of virgin aluminum in pig and ingot form, within the past year the Aluminum Company of America has installed a complete and extensive aluminum bronze powder mill to produce aluminum paint pigment at its Alcoa Works in Tennessee. For ten years, it should be noted, this same plant has produced aluminum sheet in large quantities, although the equipment originally installed had to do only with the electro-chemical reduction of refined ore into metallic aluminum.

The development of mills to fabricate aluminum, in response to a growing industrial demand for these products, is itself a part of the industrial growth that fathered such development. From its start, the aluminum industry in the South has been largely a "home industry" in a natural and unforced manner, consuming vast amounts of native material and home labor in huge water-power developments, in building two model industrial towns, and in maintaining steadily mounting payrolls that flow through local arteries of trade.

In North Carolina the production of aluminum centers about Badin, near Salisbury, and in Stanly County. At this works, six pot rooms have been built since the first was erected in 1916. A carbon plant supplies the necessary electrodes and pot-lining material, while three power houses feed the pots with their required current. All three stations are on the Yadkin River; The Narrows power house is at Badin, Yadkin Falls is several miles down river, and High Rock is about thirty miles upstream.

The town of Badin is entirely company-built, with streets, water supply, school buildings, church facilities, club accommodations, all built or furnished by the company that has changed wilderness to industry, housing its employees in model homes and healthful surroundings.

The city of Alcoa, adjoining Maryville, in Blount County, Tenn., has been built around a reduction plant which started in the spring of 1914. In 1919 a carbon plant was built to supply electrodes for this reduction unit; a year later a sheet mill was completed. In 1929 an aluminum bronze powder plant was built to manufacture the metallic pigment used in aluminum paint. This addition was built in direct recognition of the importance of the South as a paint-consuming field both industrially and for the home.

During these fifteen years the original single pot-room installation has been added to until today there are ten pot rooms, with other buildings required to maintain these production units. Power is transmitted to Alcoa from the Cheoah and Santeetlah power houses of the Tallassee Power Company located up river from Alcoa; a third source of power will shortly be utilized when the station at Calderwood, further up the Little Tennessee River, is completed.

From a handful of employees, the payroll has increased to a total of approximately 3000 men. The town of Alcoa occupies land which in 1913 was almost entirely made up of farms on the outskirts of Maryville. Model homes have been built for employees, streets have been paved, adequate schools, hospital, churches, and other community activities are well housed and maintained. Blount County has advanced during these years of aluminum development from among the ten poorest of the ninety-five counties in Tennessee to a rating of the tenth county in taxable wealth.

The ore of aluminum is bauxite, mined largely in Arkansas and in South America. It contains aluminum oxide with water of crystallization and impurities consisting mainly of iron oxide, silica, and titanic acid. The ore is purified at East St. Louis, Ill., through the use of a hot sodium hydroxide solution, which takes up the aluminum as sodium aluminate. After a filtering process has separated the aluminum-bearing liquor from the gangue, aluminum oxide is precipitated and thoroughly dried under intense heat. This oxide, called alumina, is shipped to reduction plants for conversion into metallic aluminum.

Hall's process of reduction involves a solution of alumina in molten cryolite, through which an electrical current is passed to bring down metallic aluminum at the bottom of the electrolytic pot in which this continuous production of aluminum takes place. These pots are steel shells lined with a carbon mixture, forming the cathode, while carbon rods lowered into the molten mixture of cryolite and alumina act as the anode. The reduction of alumina to metallic aluminum involves a heavy expenditure of direct current electricity and of carbon electrodes.

Aluminum, taken from the reduction pots periodically, is poured into pig form, and is later remelted under close supervision, by chemical analysis and pyrometric control, to produce exact grades of pure commercial aluminum ingot or of standard alloys containing small amounts of copper, manganese, magnesium, silicon, etc., singly or in combination.

From the central research laboratory at New Kensington, Pennsylvania, branches of Aluminum Research Laboratories are maintained at all plants to perform the necessary work in connection with the technical control of processes as well as to carry on specified projects involving experimentation with new products and new processes. From the purification of the ore to the control of alloys, the aluminum industry leans heavily upon chemical analysis and research in controlling standard processes and in developing new products and methods.

The continued growth of aluminum-producing units can be indicated roughly by considering the industries that now consume the major portion of each year's production of aluminum. The development of strong aluminum alloys has brought strength equaling that of mild steel to this metal so long chosen for its lightness alone, and as a result, aluminum has a wide circle of outlets.

In aviation, aluminum is used for all pistons and for the great majority of propellers. The representative airplane engine employs aluminum for 50 per cent of its net volume, while fuselage and wing structures show an ever-increasing trend toward an extensive application of "Alclad" sheet and other forms of fabricated aluminum.

"Alclad" sheet has an inner core of strong aluminum alloy; the two outer surfaces are composed of thin layers of pure aluminum. This recently developed variety of sheet thus combines the strength of the inner core with the exceptional resistance of pure aluminum to many forms of corrosion.

Aluminum furniture, made of sheet, formed and welded together to avoid all joints that might fail, has met with approval for such uses as dining car equipment, and for library, hotel, restaurant, and office installations—where metal furniture that is light is a distinct economy over wood.

In the electrical field aluminum is extensively used in cable form for transmission lines. Usually this cable has an inner core of high-strength steel stranding. A total of approximately 600,000,000 pounds of aluminum cable, steel-reinforced, is in service today. In this connection the abundant water power of the South, that invited the location of aluminum reduction works, has afforded an attractive market for aluminum electrical conductor cable. In this field aluminum busbar is a companion product of aluminum cable.

Aluminum in architecture has shown remarkable growth in use during the past several years, supplying the demand for a white metal appropriate to modern architectural treatments, with an entirely satisfactory resistance to atmospheric corrosion. Many of the important new buildings in New York, Chicago, Pittsburgh, and other cities throughout the United States have employed aluminum as a material for spandrels, ornamental castings, window sills, copings, and other features requiring an ornamental metal that is durable. For residences, aluminum shingles with all accessories have been developed and are being sold; for industrial purposes corrugated roofing and siding, as well as standing and batten seam roofing, supplies a growing need for long-service, maintenance-free installations.

In transportation aluminum is being adopted for truck, railway coach and street car bodies. The field of household electrical appliances has long been a steady market for aluminum in many forms. Collapsible tubes for tooth paste, sealing caps for bottles, and foil for candies, cigars, tea, etc., comprise a steady outlet in the packaging of food and allied products.

Recently, equipment has been completed to produce strong aluminum alloys in structural shapes, similar to those in which iron has been a familiar material. Channels, I-beams, and other shapes can now be produced in aluminum in sizes up to fourteen inches in depth by eighty-five feet in length. Where power is expended to move weight, these structural members made of aluminum are finding many fields in which they offer an attractive economy.

When aluminum was first introduced as a commercial metal, about forty years ago, many enthusiastic predictions were made concerning the future of the new and wonderfully light metal. Many of these predictions will forever remain unfulfilled, but the introduction of strong aluminum alloys has brought some of them, at least, to a surprising degree of accomplishment. The industry which had its birth in the electrochemical experiments of Charles Martin Hall in 1884, and which struggled for years to learn how to use its product, so that others might in turn be taught, can now look forward to a constant increase in consumption, even in those fields hitherto reserved for heavier metals.

Recently constructed aluminum production and fabrication units in the South have a double significance in relation to the quickening of the South's industrial tempo; a minor importance measured by the part these newer plants themselves play in this accelerated trend; a major value when one notes in the southern field the many outlets for the aluminum produced there. Textiles, gas, oil, water resource development, sulfur, iron, and steel—all mean a market for aluminum in large quantities in various forms: paint, apparatus, electric transmission cable, busbar, and metallurgical ingot. Other industries increase the scope and total of the aluminum market, which is further benefited by the high average standard of living incident to a region adapted to agriculture and rich in natural resources.

CHAPTER XXVI

MANUFACTURE OF INSULATION BOARD AND PRESDWOOD BY THE MASONITE PROCESS

Robert M. Boehm, Masonite Corporation, Laurel, Mississippi

The Masonite Process, which converts wood waste into Insulation Board, Quartrboard and Presdwood by means of an explosion process, has attracted a great deal of attention both because of the novelty attached to shredding wood by rupturing it internally under the influence of extremely high steam pressure and because of the economic importance of an industry which utilizes a waste material and converts it into products of great commercial value.

In the last four years the Masonite Corporation has developed from a theory into a commercial plant with an annual capacity of over 130,000,000 square feet of boards. The products are Insulation Board, Quartrboard, $^3/_{16}$ Presdwood, and $^1/_8$ Presdwood.

Insulation Board is $^7/_{16}$ inch thick and weighs 750 pounds per thousand square feet; Quartrboard is $^1/_4$ inch thick and is of the same weight; $^3/_{16}$ Presdwood is $^3/_{16}$ inch thick and weighs 1000 pounds per thousand square feet; $^1/_8$ Presdwood is $^1/_8$ inch thick and weighs 750 pounds per thousand square feet. The specific gravity of Insulation is 0.300, of Quartrboard is 0.600, and of $^3/_{16}$ Presdwood and $^1/_8$ Presdwood is 1.10. The tensile strength of Insulation Board is over 200 pounds per square inch, of Quartrboard over 500 pounds per square inch, and of $^3/_{16}$ Presdwood and $^1/_8$ Presdwood over 4000 pounds per square inch. All these products are made in large 4 foot × 12 foot panels.

Masonite Insulation is widely used for its insulating and acoustical properties. Quartrboard, because of its insulating value and structural strength, is incorporated into many pieces of equipment as an integral part of the structure. Presdwood is an entirely new article of manufacture and is produced only by Masonite. It is in many ways the most interesting and unusual development in the board industry. It is extremely hard and dense and one surface is very smooth, lending itself perfectly to any type of decoration. It is extremely water resistant and this, added to its great strength and rigidity, makes it very valuable as a structural material.

It is impossible to enumerate all of the uses of Presdwood. It is rapidly replacing wood for concrete forms, for when the Presdwood is stripped from the form, the concrete is smooth and without defects and requires practically no further work. Furthermore, the Presdwood may be re-used several times. Presdwood is used extensively in the automobile

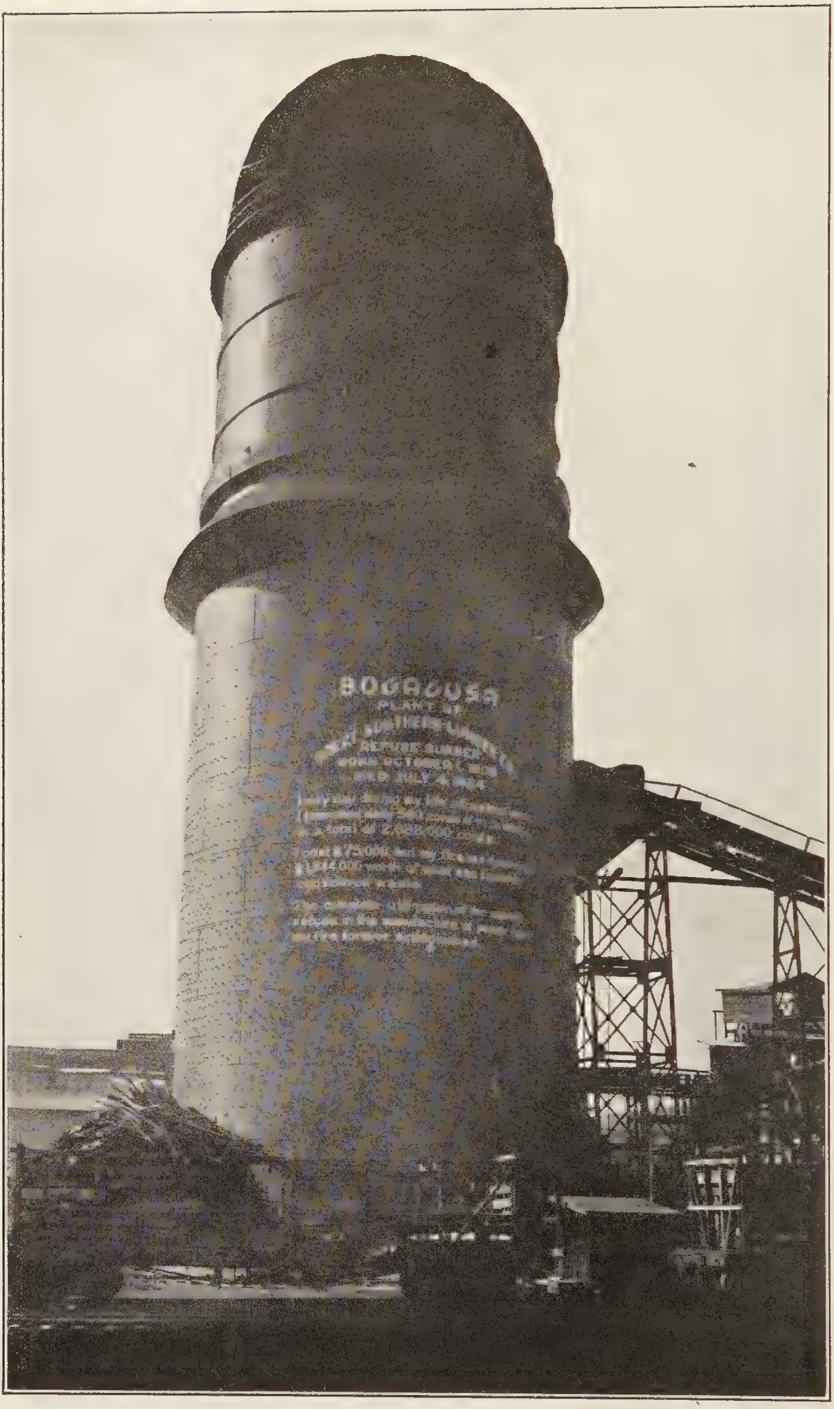


FIGURE 17.—A HUGE REFUSE BURNER, WHICH HAS BEEN IDLE FOR OVER 5 YEARS

The lettering on this monument to waste reads: "Every day during my life of sixteen years I consumed daily 560 cords of waste wood, or a total of 2,688,000 cords. I cost $75,000 but my fire has destroyed $1,344,000 worth of what was formerly considered waste. The complete utilization of sawmill refuse in the manufacture of paper has my fire forever extinguished."

and moving picture industries. It is also perfectly adapted for the construction and remodeling of homes and buildings.

At present the Masonite Process utilizes long leaf pine waste but experiments prove that any type of wood waste is suitable. The wood is reduced by chippers and hogs to chips approximately 0.75 inch long. These are screened to remove sawdust and slivers and are fed directly to the guns.

The guns are 20 inches in diameter and 5 feet high and are equipped with quick-opening hydraulic valves. When the gun is loaded with chips, low pressure steam is admitted at 350 pounds per square inch. They are left at this temperature for thirty to forty seconds and the high pressure steam is then admitted which brings the pressure up to 1000 pounds per square inch. Five seconds later the discharge valve is opened and the chips pass through a port in the bottom of the gun and explode immediately, due to the high internal pressure. This completely ruptures the chips and produces a mass of long fiber bundles.

The fiber is refined by passing through rod mills and other refiners, during which time the consistency, temperature, and pH are carefully controlled. It is waterproofed with a sizing emulsion and passes directly on to the forming machine.

Here it is formed into a continuous wet lap 0.75 inch thick and slightly over 4 feet in width. The wet lap is cut into 12.5 foot lengths and fed into large hydraulic presses. These presses are equipped with steam-heated platens, a wire screen on which the wet lap is inserted and removed, and a polished chrome plate which imparts hardness and luster to the surface. In the manufacture of Insulation Board and Quartrboard, the presses are equipped with stops to hold the board at the desired caliper. In the manufacture of Presdwood, the full pressure of 300 pounds per square inch is applied to the board. This causes the fibers to become hard and glassy and to weld together into an extremely dense, strong product.

The boards then pass through a humidifier which is maintained at 80° F. and 100 per cent relative humidity. This equalizes the moisture content of the boards to 7 per cent, insuring a moisture equilibrium and preventing expansion and contraction in usage. From ten to twelve hours in the humidifier is necessary to obtain this result.

A chrome-plating plant has been installed to plate and polish the large plates which are used in the presses to give Presdwood its dense, smooth surface. Since we are practically pioneers in the chrome plating of objects of this size, a great deal of original work was required.

The control of the entire process is carefully watched from the wood and other raw material to the finished product. The wood is tested for moisture, bark, and imperfections. The guns must be watched very closely, since when dealing with pressures of this magnitude slight changes are very important. The refining is carefully watched and the fibers compared with standards which have been set up. Machine operation, press operation, and the auxiliary processes such as the humidifier, chrome plating plant and converting and finishing are carefully controlled. The finished board is subjected to routine tests for weight, caliper, moisture, water absorption, transverse strength, deflection, tensile strength, bond strength, and specific gravity as well as periodical tests which demonstrate its suitability for various applications.

Throughout the process, water is used as a conveying medium. This water is carefully controlled for temperature, pH value, and concentration of suspended and dissolved solids. A clarifying system is in operation which removes the bark and other undesirable materials and allows the water to be re-used, thus conserving the heat and the dissolved solids.

A large research department is maintained which may be subdivided into four main classes. These are technical control, mill research, fundamental research, and development. The research department is equipped with a complete semi-commercial apparatus as well as departments devoted to chemical analyses, physical methods, optical analyses, testing of machines and instruments and studies of applications. The Masonite Corporation feels that only by intensive research activities can it continually advance the quality of its products and continue to maintain its present position in the industry.

CHAPTER XXVII

THE UTILIZATION OF BAGASSE IN THE MANUFACTURE OF CELOTEX

Elbert C. Lathrop, The Celotex Company, Chicago, Illinois

Ten years ago bagasse, which is the residue after the sugar has been extracted from the sugar cane, served its only useful purpose to mankind as an inferior fuel for sugar plant boilers, despite the fact that much effort and many thousands of dollars have been spent in research directed toward other uses. Today, in a converted form, it has found its way into 300,000 homes and dozens of industries, more than a billion square feet now being in use in the United States. This converted form is known as Celotex, a structural and industrial thermal insulation board.

This change in the status of an agricultural waste came about as a direct result of research carried on by a group of experienced insulation engineers. In this work many fibers were studied, not only straw, cornstalks, flax, etc., but also fibers not common to North American agriculture. The search was for the fiber best adapted from a technical and an economic position to produce the ideal thermal and sound insulation in structural board form. Bagasse from the sugar cane was chosen after some years of search.

Like wood, bagasse is cellulose, but it has several advantages over wood. It is a seasonal crop reproduced annually and grown in enormous quantities for its sugar content. Its fibers are among the longest and toughest cellulose fibers commercially available. It is this length and strength of fiber that makes a structurally sturdy building board when the fibers are properly felted together. Each fiber contains thousands of tiny sealed air cells which tend to bar the passage of heat and form the basis for the board's insulating qualities. The felting of these fibers in the manufacturing operation results in a product containing from 75 per cent to 85 per cent air cells.

The solution of many difficult problems was involved in the commercial production of Celotex, not a few being the result of a determination to use a continuous process made as automatic as possible. The secret of successful manufacture is control of uniformity of product, and engineering rather than rule-of-thumb practices.

As the bagasse comes from the sugar mill it is baled by special machines and stacked in pyramidal piles until needed at the Celotex plant. At the plant the bales are broken open and carried on conveyors into the plant where the bagasse is shredded, cooked, washed, and refined to form a pulp made up of fibers finely divided and properly assorted in length.

These operations are somewhat similar to those in paper mills. Waterproofing chemicals are added to the pulp, which is then fed to a board-forming machine. The water is drained through the mold roll wires as the fibers felt themselves to a sheet thickness of about one inch. The felted sheet then passes through baby and large press rolls which squeeze out as much water as practical and reduce the sheet to its final approximate thickness. No binder is used in the felting operation, except the physical interweaving of the fibers themselves. The operation is continuous, the machine turning out a board 12.5 feet wide at a rate depending on thickness, which is automatically maintained uniform.

After leaving the press rolls the board is carried on conveyors through drying ovens 1000 feet long. The speed of the conveyors and the temperature (300 to 450°F.) of the ovens are so correlated that the board is thoroughly dried when delivered at the outlet of the drier.

When the board leaves the drier, it runs on a conveyor over an automatic cutting machine, which first trims the edges and cuts the board into three sections 4 feet wide, and then, without stopping the forward movement, cuts it into the desired lengths.

The entire production is subjected to rigid laboratory tests and physical inspection. No board failing to meet specifications is shipped—this, like the "broke" in paper mills, being reprocessed. The now finished board is either shipped or, in case of many industries, is fabricated to order.

As a structural insulating material, Celotex makes buildings warmer in winter and cooler in summer by preventing the passage of heat. As a sound-absorbing material it is used in offices, factories, radio and movie studios, auditoriums, and theaters throughout the world. In industry its uses range from radio receiver to mechanical refrigerator manufacturing. In 1922 approximately 18,000,000 square feet were produced, while the capacity of the mills is now 500,000,000 square feet.

About four years ago, in order to insure the bagasse supply, this industrial group became interested in the sugar industry, and through affiliated companies now owns 50,000 acres of plantations in Louisiana, with five sugar mills of a grinding capacity of 8000 tons per day. In Florida, the Everglades from Clewiston to Canal Point, in an area of about 200,000 acres, are being converted into sugar plantations. This year something over 25,000 acres are planted to cane, of which 11,000 acres are being milled in two mills of a combined capacity of 4600 tons daily grinding.

Last year a paper mill was purchased in Louisiana in which bagasse is being used to manufacture paper and like products.

CHAPTER XXVIII

THE UTILIZATION OF BLAST FURNACE SLAG IN THE SOUTH

George J. Fertig, Chemical and Metallurgical Engineer, Birmingham, Alabama

The blast furnaces of Alabama, located principally in the Birmingham District, produce pig iron at the rate of 2,700,000 tons annually, a large percentage of which is basic iron which is later made into steel. The iron ores of Alabama which are smelted to produce this pig iron are not concentrated as are the ores smelted in northern furnaces and hence there are approximately 1800 pounds of slag produced for each long ton of pig iron made. Some 2,300,000 tons of blast furnace slag, therefore, are available from the furnaces of the district annually. A very large portion of this tonnage has been converted to profitable use either as a basis for slag cements or as aggregates for cement or bituminous concretes. This formerly considered waste material has been converted into valuable materials for building and highway construction on a large scale.

Chemically, the slag of the blast furnace is made up of various combinations, mainly of lime, silica, alumina, and magnesia. These four constituents are united in various ways and proportions to form some eighteen or twenty separate compounds whose presence in the slag is determined by the chemical composition of the fluxes and ore impurities, as well as by the rate of cooling of the slag after it has left the blast furnace. Basic slags, which are the ones utilized more often, vary in composition from 41 to 46 per cent in lime, 31 to 35 per cent in silica, 11 to 16 per cent in alumina, and from 1 to 5 per cent in magnesia. In addition these slags contain from 0.8 to 1.4 per cent of sulfur as calcium sulfide and small quantities of iron, manganese, and phosphorus.

Physically, the cold slag is a light-gray, lava-like mass which is more or less porous. Nevertheless it is a tough, abrasive material which is quite hard, usually breaking up into cubical pieces. Its true specific gravity approximates 2.60 but because of its porosity its apparent specific gravity usually runs around 2.30. Although porous, it possesses remarkable qualities of toughness, having a per cent of wear of from 5.0 to 5.7 as a general rule. These chemical and physical properties are responsible for its present extensive use in the southern states in general as a basis for cements and as an aggregate in construction.

The manufacture of slag cement in the United States was first attempted in Chicago in 1899, then in a number of other places in the country. At the present time the only plants in operation manufacturing puzzolanic cement are located in the Birmingham district. The making of slag cements or mortars consists in the grinding together of water-granulated slag and hydrated lime in proportions varying from 80 per cent slag and 20 per cent hydrated lime to 30 per cent slag and 70 per cent lime. Basic blast furnace slags in contra-distinction to foundry or acid slags have a setting power when ground very finely which is closely connected with the lime and silica content and with their rate of cooling through the upper temperatures. For some cements 43 to 45 per cent of lime and less than 4 per cent of magnesia are preferred, while for others, slags of less basic character and equally low magnesia contents are desired. These slags are run directly from the furnace in thin streams into large bodies of water so as to secure rapid chilling as well as a high degree of subdivision of the mass. The water is drained off, the granulated slag dried, proper additions of hydrated lime made and the mixture ground mechanically in ball mills to a fineness where at least 95 per cent will pass a 200-mesh sieve. The product is then stored or sacked and shipped for use. A cement of this type has seen considerable use in the concrete base construction of many of the asphalt-surfaced streets of Birmingham and other southern cities. It is used in mixtures with portland cement in various proportions in much of the building and industrial construction of the district. Still another puzzolanic mixture possesses properties which are responsible for its use as a brick mortar constituent. Setting time of these cements depends largely upon the amount of hydrated lime in the mixture and in all instances is much longer than in the case of portland cement. An increase in density of the concrete is one of the qualities attributable to these puzzolanic cements.

The largest portion of the basic slag of the district is processed for use as aggregates. The slag leaving the cinder notch of the furnace is conducted to specially prepared pits of great length and so arranged as to allow the molten product to flow down at a gradient and cool in layers. When cool the solid slag is shoveled into cars, watered, crushed, and screened into various sizes for particular adaptations. Some of the product is used as aggregate in portland or puzzolanic cement concrete while some is utilized with tar or asphalt binders in bituminous construction. Smaller sizes are manufactured into brick and building tile, used in roof and shingle making or employed as inert fillers for asphalts or fertilizers. Physically slag is well adapted to any case of cementing with a binder, having a porous surface and being relatively light for transportation. It was thought at one time that the sulfur content of the slag, being somewhat leachable, would be detrimental to reinforcing steel in the concrete but careful investigation and experience have revealed no undesirable consequences arising from this constituent.

Information so far gained on the behavior of blast furnace slags with reference to the relationship of the hydraulic properties to the various chemical and physical constitutions is still quite incomplete. A second field of investigation might well include the effect of the rates of cooling on the production of sounder slags for use as aggregates. A third field of endeavor could profitably be that of an investigation of the mechanism of hardening of puzzolanic cements.

CHAPTER XXIX

THE IODINE CONTENT OF SOME SOUTH CAROLINA PRODUCTS

Roe E. Remington, South Carolina Food Research Commission, Charleston, South Carolina

The general assembly of the state of South Carolina at its 1928 session created a commission and provided funds for the purpose of making studies on the mineral elements contained in foods grown or produced in the state. The commission consists of six members: the president of the state university, the president of the state agricultural college, the dean of the medical college of the state, and the secretary of the state board of health, ex officio; Dr. William Weston, pediatrician and student of nutrition of Columbia, and Dr. R. R. Walker, a practicing physician of Laurens, the last two appointed by the governor. A laboratory was established in affiliation with the Medical College of the State of South Carolina at Charleston.

It is the aim of this commission to accumulate information, on a more complete scale than has heretofore been attempted, as to the occurrence of the so-called mineral elements (mineral elements in the sense that they are usually separated and determined as inorganic salts) in the various substances used as food for man or domestic animals. Among these elements the most common are calcium, phosphorus, magnesium, chlorine, iron, and the alkali metals. Others, however, which have attracted recent interest are iodine, fluorine, manganese, copper, and zinc. While the exact part which some of these latter elements may play in nutrition is as yet problematic, the rôle of iodine has been quite definitely established.

Endemic thyroid enlargement, myxedema and cretinism are results of iodine deficiency. The studies of McClendon on surface waters and on vegetable foods have shown that there is very little iodine in the food and waters of that part of the United States in which simple goiter is a serious problem. In fact, no surface waters in the country contain sufficient iodine to provide entirely for the needs of nutrition. Goiter is not endemic in South Carolina; examination of over seventeen thousand high-school students in twenty counties by the State Board of Health having shown an incidence of 3.8 per cent, as compared with 70 per cent or more for the upper Mississippi Valley, 40 per cent for southern Ohio and Colorado, etc. It appeared then, that South Carolina would be a desirable place to make an exhaustive study on the occurrence of iodine in human environment, and this project was accordingly taken up in the laboratory.

Careful analyses of a wide variety of vegetables show that iodine is extremely widely distributed throughout the products of the agriculture of the state in amounts ranging from 100 to 1000 or more parts per billion, these amounts being several times greater than have been previously reported from anywhere in the United States (Table I).

TABLE I

Iodine Content of Some South Carolina Vegetables and Fruits

(Parts per billion, dry basis)

Green vegetables	*Number of samples*	*Average iodine content*	*Fruits*	*Number of samples*	*Average iodine content*
Asparagus	26	285	Blueberries	2	206
Green beans	14	210	Dewberries	1	169
Beet tops	3	657	Peaches	3	162
Cabbage	17	263	Pears	1	65
Carrot tops	6	433	Strawberries	5	181
Chinese cabbage	1	300	Tomatoes	8	112
Collards	3	232	Watermelon	1	402
Cucumbers	2	530	*Roots*		
Egg plant	3	187	Artichokes	1	182
Kale	2	278	Beets	9	182
Lettuce	13	912	Carrots	16	213
Mustard	2	224	Irish potatoes	76	211
Okra	3	223	Rutabagas	5	200
Onions	6	222	Sweet potatoes	70	98
Pimentos	1	150	Turnips	13	271
Rape	3	300	*Seeds*		
Spinach	19	692	Cottonseed meal	1	140
Summer squash	7	625	Peas	3	136
Turnip tops	7	376	Oats in hull	1	20
			Peanuts	1	67
			Rye in hull	1	86

TABLE II

Iodine Content of Potatoes in Relation to Distance from the Sea

Distance from sea	*Number of samples*	*Iodine content in parts per billion dry basis (average)*
0– 50 miles	19	180
50–100 miles	16	213
100–150 miles	15	223
150–200 miles	15	249
200– miles	4	266

For the purpose of a systematic survey, samples of Irish potatoes were collected from all parts of the state and results show a slight but definite progressive increase in iodine as we go from the coast to the mountains (Table II). This finding is not in agreement with the accepted theory that salt spray from the sea is the predominant source of iodine. The ratio of chlorine to iodine in sea water is a million to one, and some streams in upper South Carolina have been shown by Mitchell to contain one-fourth as much iodine as does sea water, yet the streams are far from being salty. The most evident explanation lies in the theory that the source of iodine is in the disintegration of granitic rocks in the Blue Ridge, and Fellenberg has reported more iodine in granitic rocks than sedimentary rocks. In view of the difference in the physical and chemical properties of the soil in the different parts of the state, soils of the Piedmont being more colloidal than coastal plain soils, and the fact that Chilean nitrate of soda (which carries a fraction of a per cent of iodine) has been used in South Carolina agriculture for more than fifty years, the exact source of the iodine may be questionable.

Doubtless systematic surveys of iodine in the environment of dwellers in every locality will contribute materially to our knowledge of the endemic goiter problem. The South Carolina work is the first attempt to do this on a thorough scale. Other states are following. Attempts are being made by the South Carolina Natural Resources Commission to capitalize this work in a commercial way in encouraging immigration into the state from goitrous regions, and in creating a demand for South Carolina vegetables in such regions.

CHAPTER XXX

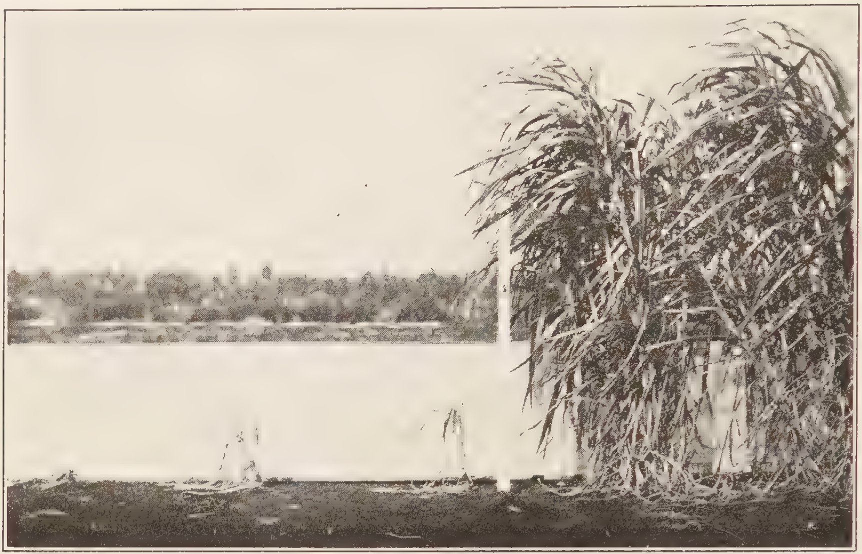
COPPER SULFATE SOLVES THE CENTRAL PROBLEM OF SOIL FERTILITY IN THE FLORIDA EVERGLADES

R. V. ALLISON, EVERGLADES EXPERIMENT STATION, FLORIDA

At the upper or northern margin of the Everglades along the immediate shore of Lake Okeechobee, which represents the head of this vast overflow area that slopes so imperceptibly to the south, there is to be found a narrow belt of true muck that is comparatively high in mineral content. The great bulk of the Everglades area lying to the south of this, however, is made up of a remarkably fine type of lowmoor peat derived for the most part from the long-time growth of a heavy sedge or "sawgrass" (*Cladium* sp.). Here, then, is to be found a broad, continuous, and exceedingly flat plain almost as large as the combined areas of Rhode Island and Connecticut that has been built up from the seasonal residues of this tall grass with which it has been covered for many centuries. It is with this latter type that the present discussion is particularly concerned. Under conditions of local drainage the grass cover is rather rapidly giving way to a succession of other plant types through the year. As for dense thickets, tall trees with moss and impenetrable sloughs of deep mud—these and other similar conceptions are things of fancy purely in their longtime association with the Everglades as it exists in the minds of many people.

With the early breaking, immediately following drainage, of our brown, fibrous peat that has been developing for so many centuries under conditions of partial to complete submergence and anaerobicity, the first and most important problem encountered by the Experiment Station during the early period of its development was the rather prompt and complete failure of practically all agricultural crops when planted in this soil without special treatment. A notable exception to this general rule was found in the case of the potato.

Under general field conditions unusually favorable development even of some of the plants more sensitive to this soil condition was observed to follow from time to time upon areas where the previous crops such as potatoes or celery had required the application of Bordeaux spray as a matter of course in the control of plant diseases. It was this observation in particular that led to systematic studies with copper in the soil-plant relation in this area. It appears that similar observations of such residual effects of this spray have developed into this same line of study and application upon organic soils in New York, in Holland, and in Germany, and that these observations were made for the most part quite independ-



Stearns Photo Shop, West Palm Beach

FIGURE 18.—RESPONSE OF SUGAR CANE TO TREATMENT OF RAW SAWGRASS SOIL WITH THIRTY POUNDS OF COPPER SULFATE PER ACRE

Left, untreated; right, treated.

ently. The work with special elements here in the Everglades was quickly extended to include a number of other ions.

The extraordinary character of the response of practically all agricultural plants to copper sulfate when applied to our brown peat soils led to its very early adoption as a soil amendment under field conditions. Whereas under experimental conditions in the field satisfactory results and normal development of practically all plants have been obtained with the use of twenty-five to thirty pounds or less of copper sulfate per acre, the common practice upon freshly broken land is to apply fifty to seventy-five pounds, particularly to provide against irregularities of distribution which invariably make for an irregular stand and development of the crop. As a matter of convenience and economy when other fertilizer materials are being used at the same time, the copper sulfate (or other special salt) is incorporated into the mixture in such quantity that distribution will be at the proper rate when applied as the mixture.

The need for copper in connection with crop response upon brown fibrous soils has been so thoroughly demonstrated and so repeatedly experienced by the growers that its application is now regarded as an absolute necessity upon freshly broken areas. Activities upon the "sawgrass" soils are advancing at such a rate, furthermore, that already many carloads of this salt alone have been used for this purpose. There is evidence, too, of a very pronounced and satisfactory residual effect from crop to crop and from season to season. The establishment of these relations constitute one of the many important problems from the practical as well as from the scientific standpoint. In discussing the use of this or other special chemicals upon a soil of this type, however, emphasis always has been laid upon the need for careful attention to its rather pronounced deficiency in terms of phosphoric acid and potash, particularly with the establishment of heavy cropping that is found possible through the use of such amendments. The importance of balancing the soil treatments under such conditions is readily apparent.

So far as the actual rôle of copper in its unusual relation to plant development in such a soil environment is concerned, it is apparent that we have a problem that at once involves plant physiology and soil chemistry in a very intimate way.

In popular treatises upon the subject, the Experiment Station usually has emphasized the "nutritional" viewpoint and always has advised the application of this and other chemicals of similar nature in the same way or along with such other fertilizer materials as are more commonly used in practice. The reason for doing this is readily apparent. However, in the earliest studies along this line in the field it was observed that there was concerned something more than a simple plant nutrient effect; likewise something more than a simple soil treatment relation. In other words, though, it is probable that one of the primary effects of the treatment is in the protection of the advancing root system as it penetrates in a normal way to all parts of such a soil environment against exceedingly small concentrations of certain organic toxins contained therein, it has become apparent that this protective effect, to a certain extent at least, comes from within the plant and is, therefore, preceded by actual assimilation of the protective ion. Thus, as early as the autumn of 1927 in working with sugar cane, the injection of copper sulfate directly into the seed piece was found to produce very marked response in the young plants developing therefrom, though the treatment in this case was held absolutely independent of the soil environment. Besides indicating the very intimate chemical and physiological relation that exists between the plant and the soil during the progress of such plant responses, studies of this type also have shown rather definitely that soil sterilization effects cannot be playing anything of a primary rôle in this connection. These have been referred to rather frequently in the past.

Any treatise, however brief, upon the important place copper sulfate is finding in the agriculture of the Everglades should not be concluded, however, without some reference to the unusual results that are being obtained with the use of manganese and of zinc in a similar way upon these soils. Both of these elements also are commonly used in the form of the sulfate.

Upon soils rendered particularly alkaline or "sweet" through earlier burning or otherwise, manganese sulfate is found to give very important results with a large number of crops. It is usually applied at about the same rate and in the same way as copper sulfate. Situations are frequently found in which the need for manganese treatment is quite as serious as that for copper, the response to which is so well known. In the case of zinc sulfate it is found particularly important to combine this element with the copper treatment where the planting of certain crops is planned to follow rather closely upon the breaking and treatment of fresh areas of brown fibrous peat. Most work has been done with the peanut plant in connection with this combination treatment and the results have been very striking. Unless the zinc is applied with the copper under these conditions the plant experiences a considerable delay during its early period of development and actually passes through a definite period of dwarfing that lasts several weeks. It then enters upon a later period of continuous and normal growth that brings it to maturity. This response is particularly striking since the use of zinc alone has never shown more than a very slight response of any kind and this has always been of a very transient character.

CHAPTER XXXI

XYLOSE*

Warren E. Emley, U. S. Bureau of Standards, Washington, D. C.

The city of Anniston, Alabama, is becoming internationally known as the place where xylose is made. Another chapter is being written in the romance of cotton. Almost within the present generation, man has learned the value of cottonseed oil, cottonseed meal, and cotton linters. After the recovery of these three products, there is nothing left of the seed except the hard woody outer shell, which for present purposes we may call cottonseed hull bran.

This bran does not differ essentially from similar parts of other plants, but does contain more xylose as indicated by the following figures:

Material	*Per cent xylose by weight of bone-dry material*
Bagasse	25 to 30
Artichoke tops	15
Cornstalks	29 to 31
Corncobs	31 to 37
Peanut shells	23
Oat hulls	31
Cotton burrs	19
Cottonseed hull bran	40

Cottonseed hull bran is produced to the extent of something over a million tons a year; the cost of collection is and logically should be borne in part by the oil, meal, and linters; and the present market for the bran is precarious.

Xylose is a five-carbon aldose sugar which has been known to science for forty years. It has been used by biochemists and bacteriologists. The demand was so small that production could never be put on a commercial basis, and the price of about a hundred dollars a pound was not sufficiently profitable to be attractive. At the same time this apparently exorbitant price effectually stopped industrial chemists from experimenting with xylose for purposes for which it might be suited.

If xylose could be produced from cottonseed hull bran by a practicable method, then the industrial chemist would have available a new raw material, and the cotton farmer might hope for another outlet for his product. The laboratory method for the preparation of xylose relied upon the use of alcohol or glacial acetic acid to make the sugar crystallize. It was found that if the gums and water-soluble salts, which are present in the bran, are removed before hydrolysis, then the xylose will crystallize readily without the use of any precipitating reagent.

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* Published by permission of the Director of the U. S. Bureau of Standards, Department of Commerce.

The method as finally developed by Dr. S. F. Acree and his co-workers in the laboratory of the Bureau of Standards in Washington comprises the following steps. (1) Wash the bran with hot water at 10 pounds steam pressure. (2) Wash with cold dilute (0.16 *N*) sulfuric acid. (3) Digest for two hours at ten pounds steam pressure with dilute (0.32 *N*) sulfuric acid to hydrolyze the xylan to xylose. (4) Neutralize with calcium carbonate to pH 2.4. (5) Treat with carbon and filter. (6) Evaporate the filtrate to a specific gravity of about 1.28, and filter to remove the calcium sulfate. (7) Evaporate to a specific gravity of 1.35 and cool. (8) Centrifuge to separate the crystalline xylose from the molasses.

The difficulties of putting any laboratory process into commercial production are so well known that it was thought advisable to include this step in the program, at least on a small scale. Furthermore, this would provide the opportunity of making considerable quantities of xylose which could be furnished to industrial chemists interested in experimenting with it, and would give some data on the cost of manufacture.

A semi-commercial plant was therefore designed by Dr. Acree to produce 100 pounds of xylose a day, and was erected at Anniston. This plant has been operated by Mr. Walter T. Schreiber, of the Bureau of Standards, and his co-workers, since March 15, 1929. It has been found necessary to change several minor details of the original process; some of the original equipment was found to be unsatisfactory and had to be replaced; and several tons of xylose have been made.

The crude material, the product of the first crystallization, has a purity of better than 95 per cent. The impurity is chiefly calcium sulfate but there are appreciable quantities of copper, lead, nickel, etc., dissolved from the equipment. These can be largely removed by dissolving the xylose in water and recrystallizing, and can be completely removed by treating the solution with hydrogen sulfide or disodium phosphate, filtering and crystallizing. The data indicate an average production of 22 pounds of xylose in the molasses, or 15 pounds of crystalline xylose per 100 pounds of bran. The conversion cost is somewhat less than 10 cents per pound. It should be noted that this is conversion cost only; it does not include the cost of the bran, nor any overhead or profit.

Samples of the technical grade, usually about five pounds, have been sent gratis to industrial chemists who are investigating its use in the explosives, dyeing, tanning, rayon, and other industries. Samples of the recrystallized grade have been sent to other investigators for studies in food products. Samples have been sent to England, Germany, Argentine, Peru, Australia, and Japan, as well as to all parts of the United States.

Anniston was selected as the site for the factory, partly because it was desired to be near the source of raw material, but chiefly because of the offer of coöperation received from the Alabama Industrial Development Board. Under the terms of this agreement, the Swann Corporation has furnished the site, building, and equipment for the factory at Anniston, and both the Alabama Polytechnic Institute and the University of Alabama have furnished members of Mr. Schreiber's staff, besides conducting a good deal of related work in their own laboratories.

The broad vision displayed by the Honorable Bibb Graves, Governor of Alabama and Chairman of the Board, and Theodore Swann, Vice-Chairman of the Board and President of the Swann Corporation, is typical of the kind of leadership which is now making the New South. This is one of their many efforts to utilize natural resources and to build up a manufacturing industry, not at the expense of agriculture, but as a complement thereto.

CHAPTER XXXII

THE THERMATOMIC CARBON PROCESS

Carroll Miller, Thermatomic Carbon Company, Pittsburgh, Pennsylvania

The Thermatomic plant is located at Sterlington, Louisiana, in the Monroe Gas Field and has been in operation since 1922.

Thermatomic carbon is not made by burning natural gas, as in the channel process, but is made by cracking natural gas in the absence of air. The furnace in which the gas is treated is about fourteen feet in diameter and twenty-five feet high, is lined with refractory material, and is filled with checkerbrick, similar to a blast furnace stove. The process is intermittent; the checkerbrick are first heated, then the heat is turned off and the natural gas for cracking is passed through the hot checkerbrick, resulting in producing chemically carbon and residual gas. About ten pounds of carbon and fourteen hundred cubic feet of residual gas, containing approximately 85% of hydrogen, are recovered for each one thousand cubic feet of natural gas treated, when making the original carbon known as "Thermax."

The carbon goes forward in suspension in the residual gas to a cooler, in which the temperature is reduced to the desired degree by a water spray, thence to a collector where the carbon is removed from the gas by filtering through fabric bags. The carbon then goes into a conveyor which carries it to the screening and packing plant, where it is packed in paper bags containing thirty pounds each.

Throughout the entire process, the carbon is not exposed to the atmosphere and consequently it is absolutely free of dirt or any other foreign matter. The plant is controlled with thermostatic and other instruments of precision, in such a way that the quality of the product runs continuously uniform.

Thermax is particularly described above but the two other Thermatomic products that are made, Flex and P-33, are produced in similar apparatus, the heat treatment being different in each case, as are also the yields of carbon and residual gas.

Thermax is known as a "soft" carbon; its principal use is in the rubber industry. The term "soft" is relative and means that Thermatomic carbon will not stiffen rubber nearly so much as channel black. Consequently, Thermax is largely used in carcasses of tires and in other rubber goods where a soft flexible compound is desired.

The quality of Flex is intermediate between Thermax and P-33.

P-33 has only recently been introduced to the trade and the results so far obtained would indicate that it will be largely used in the treads of pneumatic tires and in inner tubes. One of its principal functions in the tread is to add to it a quality such that cracking and cutting are reduced to a minimum. Tests would indicate that P-33 will produce a better inner tube than is now being generally used.

Thermax has a gray color and the tinctorial power is low; consequently, this product has been used to but a small extent in the ink and paint industries. The undertone of P-33 is blue and it has a tinctorial power approaching channel black and should be used largely for the manufacture of printing inks and paints. The oil absorption of P-33 is low which means that a large proportion can be used in paints and printing inks without unduly thickening them.

CHAPTER XXXIII

THE PRODUCTION OF HELIUM

From Data Furnished by the Bureau of Mines

The story of helium has been called one of the romances of science. Viewed through the spectroscope, helium, made incandescent by an electric discharge, displays a bright yellow line characteristic of this gas. This line was first made visible to man when in 1868 a group of scientific investigators in India for the first time turned a spectroscope on the chromosphere, that part of the atmosphere of the sun, about 10,000 miles deep, which merges into the corona. Recognizing an element in the sun not previously discovered on the earth the new element was given the name "helium" from the Greek word "Helios," the sun. Not until the latter part of 1894 was terrestrial helium discovered, when Sir William Ramsay, the eminent English scientist, found the bright yellow helium line in an inert gas obtained from the radioactive mineral cleveite. Dr. W. F. Hillebrand, of the United States Geological Survey, had obtained this same gas from the same source but did not identify the helium in it.

Helium is found in the atmosphere in the proportion of one part in 185,000 parts. It is found in minute quantities in sea and river water, in the gases evolved from many mineral springs, and in some volcanic gases, but in none of these latter sources is the gas sufficiently plentiful to provide commercial supplies.

Helium production for use in lighter-than-air craft was started by the United States government during the World War. A thorough study was made of fields which contained helium-bearing natural gas, by specialists of the United States Bureau of Mines and the United States Geological Survey. As a result, it was established that the Petrolia gas field of Clay County, Texas, was at that time the field best suited as a source of supply for the government's initial helium development.

At the inception of the development work three plants were constructed to try out experiments on helium production. Three firms, the Linde Air Products Company, the Air Reduction Company, and the Jeffries-Norton Corporation, active in kindred lines, coöperated with the government in this project, using modifications of their processes for the purpose. Two of the plants were erected at Fort Worth and one at Petrolia, and all three were supplied with gas from the Petrolia gas fields. Funds for development work were provided by allotment from the War and Navy Departments.

Following this experimental work, a plant using the process developed by the coöperating Linde Air Products Company was constructed at

Fort Worth under the jurisdiction of the Navy Department. This plant has been operated continuously since October, 1922, and has produced probably 90 per cent of all the helium that has been produced in the world.

In April, 1929, the new government helium plant located at Soncy, near Amarillo, Texas, began operation. The helium is extracted from natural gas having a helium content of 1.75 per cent, produced from the Cliffside structure lying northwest of Amarillo. Gas from 26,000 acres of land is available to the plant through a contract between the Department of Commerce and the Amarillo Oil Company.

The helium-bearing natural gas is transported from the wells to the plant, by the natural pressure of the wells, through a welded steel pipe line eleven miles long. In the plant the gas is cooled to a temperature so low that all of the constituents except helium are reduced to liquids. This temperature is approximately that of liquid air and is lower than 300°F. below zero. The helium is drawn off as a gas and the liquids are returned to the gaseous state by allowing their temperature to return to that of the atmosphere. A part of the gas resulting from the evaporation of the liquid is used as fuel to generate power to operate the plant and the remainder is discharged into a pipe line which carries it to Amarillo where it is used as domestic and industrial fuel. The process of extracting helium is a continuous one involving pressures as high as 2500 pounds per square inch.

The helium is shipped in specially built helium tank cars owned by the Air Corps. They carry the helium under a pressure of 2000 pounds per square inch and have a capacity of 200,000 cubic feet.

During September, 1929, the plant produced 847,840 cubic feet of gas with an average purity of 97.7 per cent, at a net expenditure by the Government of only $14.01 per thousand cubic feet.*

Before the World War, helium, which had been obtained only in small amounts as a curiosity in scientific laboratories, cost about $2000 per cubic foot. The reduction in production costs to less than two cents per cubic foot is a remarkable achievement.

Two million five hundred thousand cubic feet of gas are required to fill an airship the size of the Los Angeles, and 6,500,000 cubic feet will be required to fill some of the big ships now under construction for the Navy.

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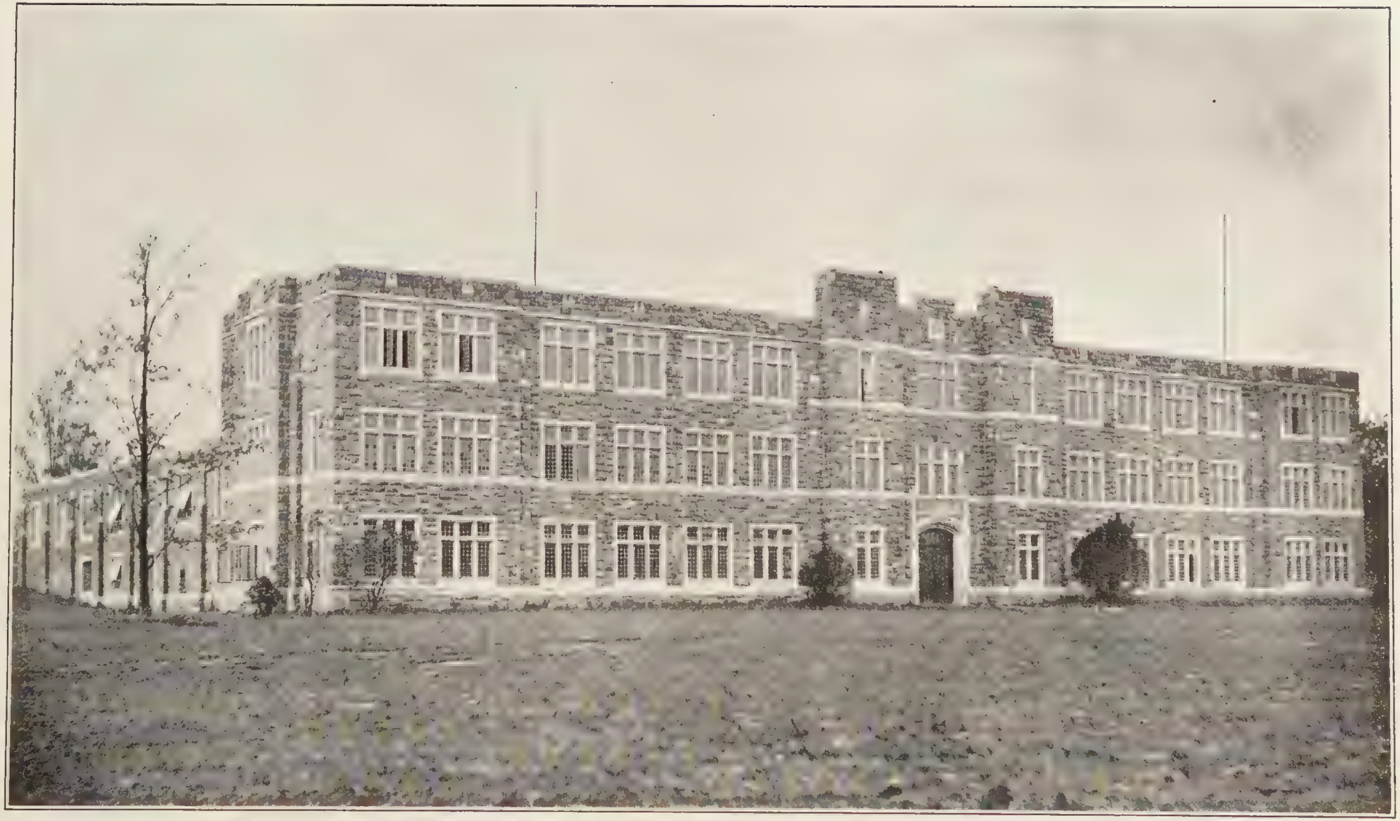
* *Editor's Note:* It is not believed that administration, depletion, and depreciation charges have been fully covered. Also, the government pays no interest, taxes, or insurance.



Casson

FIGURE 19.—DAVIDSON HALL, CHEMISTRY AND CHEMICAL ENGINEERING BUILDING, VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VIRGINIA. ERECTED 1927

CHAPTER XXXIV

A MAGNETO-OPTIC METHOD OF CHEMICAL ANALYSIS

Fred Allison and Edgar J. Murphy, Alabama Polytechnic Institute, Auburn, Alabama

This paper describes a new and highly sensitive method of chemical analysis, which promises to be of practical importance. The method is a refinement and an extension of one previously described by Allison [*Phys. Rev.*, **30,** 66 (1927)]. Monochromatic light passes successively through a Nicol prism, two cylindrical glass cells containing the substances under investigation, and a second Nicol crossed with respect to the first. The two glass cells are placed coaxially inside two cylindrical tubes around which helices of wire have been wound in such directions that the magnetic fields produced by a condensed discharge are in opposite directions in the two cells. If the same substance is placed in the two cells and the electric circuit so adjusted that the magnetic fields in the two cells are equal and opposite and are applied simultaneously (or at a time difference equal to the distance between the two cells divided by the velocity of light), the rotation of the plane of polarization in the first cell is compensated by that in the second and no light passes through the second Nicol prism. If then a different liquid is substituted in the second cell, it is necessary to displace one of the cells (thereby increasing the length of the light path between them) a definite distance in order to reduce the light transmitted by the second Nicol to a minimum. Practically the same results are obtained by the more convenient arrangement whereby the air path is kept constant and the length of the wire path is changed until the light is reduced to a minimum, since the speed of the electric impulses along the wires is found to be approximately that of light in air. The position of the minimum was thus found to be characteristic of the compound. These results were interpreted as being due to a difference in time lags in the Faraday effect behind the magnetic field in the two liquids.

While repeating some of these observations it was found that if several compounds were placed in the second cell, several minima of light intensity were observed, the positions of which were characteristic of the respective compounds present. In other words, the position of a minimum characteristic of a compound was not influenced by the presence of any number of other compounds.

In an attempt to determine the smallest quantity of any substance required to produce its minimum of light, the very surprising result was found that the minimum did not disappear until the concentration was reduced to about one part in 10^{11}. This applies to both organic and inorganic compounds [*see* Allison, *Phys. Rev.*, **31**, 313 (1928)]. The exact concentration at which the minima disappear depends somewhat upon the observer, the chemical compound, and the adjustment of the apparatus.

A large number of chemical compounds, chiefly inorganic, has been studied. A closer examination of the minima revealed the fact that each minimum is either single or composed of two or more close minima. In the case of all the solutions of inorganic compounds thus far studied, it is interesting to note that, with very few exceptions, the number of minima is the same as the number of known isotopes of the metallic elements of the compounds. Another relationship of interest is the fact that the positions of the minima depend upon the atomic masses of the metallic elements of the compounds or, more precisely, upon their chemical equivalents, the time lags of the heavier elements being shorter than those of the lighter ones. The investigations have been confined largely to an extensive series of nitrates, chlorides, sulfates, and hydroxides in solution. The method, it is believed, will apply equally well to most other compounds, both organic and inorganic. [*See* Allison and Murphy, *Phys. Rev.*, **35**, 124 (1930).]

The presence of the compound, instead of the element, is detected, the minima being at different points of the scale for different compounds of the same element. This is very surprising in view of the generally accepted theory that compounds in solution are practically completely ionized at such low concentrations.

This method of chemical analysis, though still in the experimental stage, appears to be a reliable one. A large number of analyses has been made by the authors, the results of which have checked with those obtained by standard methods of chemical analysis. The process is rapid and does not destroy the sample. Several other observers also have been able to check our results, using our set-up. In the present stage of development, however, it cannot be claimed that the method will yield dependable results unless in the hands of one who has a well-trained eye in such observations and who has acquired considerable technic in the manipulation of the apparatus. Improvements are still being introduced and it is believed that the method may ultimately be made of practical value for the average observer.

More recently the method has shown quantitative possibilities. With a series of increasing and known concentrations of a given compound in water (serving as standard), observations are carried out to find at what concentration the characteristic minima of the compound first appear. Most compounds studied reveal their presence when the concentration is near one part in 10^{11}. By making observations on a corresponding series of increasing concentrations of the unknown solution in water, one notes as before the concentration of the unknown solution in which the minima characteristic of the compound are first observed. It is then a matter of simple computation to determine the quantity of the compound in the unknown solution. As the gradations in the increasing concentrations of the solutions may be made as small as one desires, it is believed that the method affords a means of quantitative analysis sufficiently accurate for some purposes.

It is very difficult to account for the minima in such low concentrations upon the hypothesis of a lag in the Faraday effect, unless it is assumed that the Faraday effect increases very much with the frequency of the applied magnetic field or depends upon the form of the wave front of the transient surges. The effect is no doubt a time effect since the minima are produced by a change in the light path as well as by a change in the wire path. A complete interpretation, however, must await further investigations which are now in progress.

CHAPTER XXXV

MIAMI SUN-RAY RESEARCH OF THE JOSEPH H. ADAMS FOUNDATION

O. J. Sieplein, University of Miami, Miami, Florida

The outstanding natural resource of South Florida, and particularly Miami, is its sunshine. Weather service records show that the average year has sunshine on 359 days. The cloudy days usually occur in the summer and fall months. Daytime fog is very rare. Because of the low latitude the variation of sun angle is less during the day and year than for any other large city or region in the country.

With funds furnished by Dr. Joseph H. Adams of Belle Isle, Miami Beach, an observatory has been built, equipment has been purchased, and experiments and measurements are in progress. The investigation of the various qualities of the sunshine is now well under way. The work is planned as a two-year research; some observations have been in progress for several months, others have just started, while still others will be started later. Observations are also being made at a number of secondary stations in the Miami region. Such a secondary station at the University of Miami in Coral Gables has been recording tests for some time. Other secondary stations, now projected, are to be on the ocean front and on the bay front; still others will be established as the work proceeds.

The observations at the main observatory and at the secondary stations will be combined and correlated with the data of the Miami Weather Bureau and the coöperating weather station at the St. Francis Hospital on Allison Island.

Total Sunshine Energy.—This is being recorded by a Callendar Sunshine Recorder which gives a curve for the total radiation received by a horizontal surface, as a chart for each day. The curves that have already been obtained show that the energy rises rapidly in the morning and falls off rapidly in the afternoon; the average value for the day is reached before ten and is maintained until after three. Thus, the curve has a large flat maximum instead of a peak, as is characteristic of the curves for more northerly latitudes. The effective sunshine in November is comparable with that of the northern cities in August.

Minimum Wave Length in the Solar Spectrum.—A large Zeiss spectrograph (loaned by the St. Francis Hospital) with quartz prisms and lenses is mounted in an astronomical dome. The mounting and dome make possible the taking of the spectrum record at all times of day. A photographic record is made at intervals throughout a whole day; three or four such full-day records are taken each month. At present the record starts at 7.30 A.M. and ends at 4.30 or 5.00 P.M. The plate records the ultra-violet and shows the limit of short wave-length present.

A small portable Zeiss spectrograph is used for recording similar observations at other stations. This is a specialized instrument developed by Zeiss for tropical hygiene work in the German African colonies.

A Beck ultra-violet spectroscope is available for visual observation of the spectrum. This observation is made quickly and shows whether it is desirable to make the record with one of the other instruments.

Sun Angle.—The mounting of the spectrograph in the dome of the observatory carries an arc from which the angle of the sun is determined.

Angle of the sun is an important factor in the receipt of solar energy, as a low altitude of the sun means that its radiation passes through a long layer of air. Air path influences refraction; the red color at sunrise and sunset shows that the blue, violet, and ultra-violet are largely or completely lost by air refraction.

Chemical Measure of Ultra-Violet.—After much work in testing the method, a modification of the oxalic acid-uranyl sulfate radiometric process is being used to measure the quantity of ultra-violet energy. A flask of fused quartz must be used as glass is opaque to ultra-violet. This flask is filled with a solution of oxalic acid containing uranium sulfate as a sensitizing agent. After exposure to sunlight, the unchanged oxalic acid is determined by titration with potassium permanganate. The quantity of oxalic acid decomposed measures the ultra-violet.

The method has been developed from that used earlier so that it can be used for measuring the ultra-violet at several places simultaneously by untrained observers. Its primary importance is as a comparative method whose results are interpreted by means of the exact method of photometric record.

Photometric Measure of Ultra-Violet.—For this purpose an ultra-violet recorder recently developed by the Westinghouse Electric and Manufacturing Company has been purchased. This is a specialized photoelectric cell which makes record, every fifteen minutes, of the energy of the ultra-violet.

With the spectrographic record of the shortest wave-length of ultra-violet, the Westinghouse record of ultra-violet energy, the correlated measurements of the chemical effects of the ultra-violet, the Callendar record of total sunshine energy, sun angle, and the weather data, it will be possible to learn the effect of variations of the climatic factors and the inter-relations of these factors.

The most widely known effects of sunshine and particularly of ultra-violet are therapeutic. For this reason, the relations of Miami sunshine to Miami health will be studied as far as the clinical experience of Miami physicians can be brought into the record.

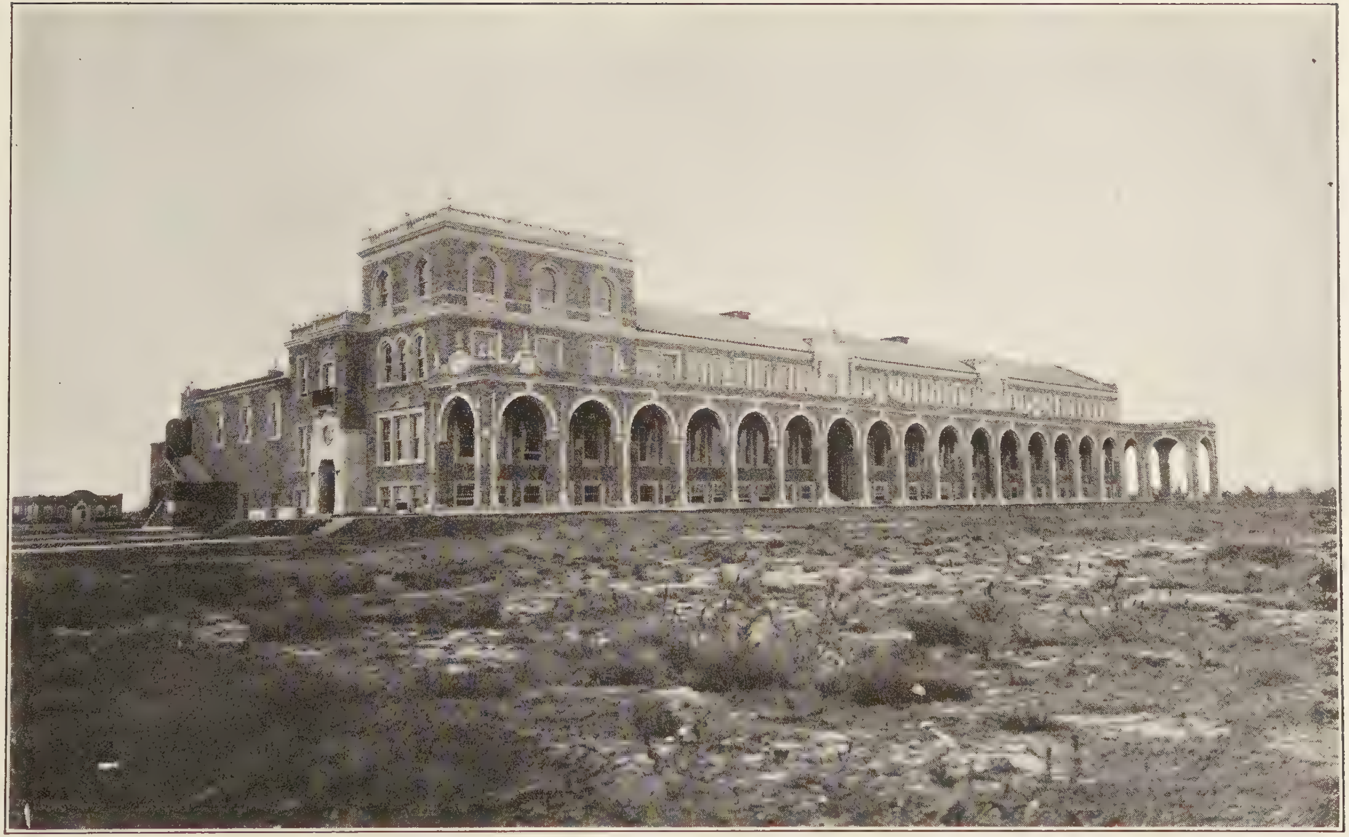


FIGURE 20.- CHEMISTRY BUILDING, TEXAS TECHNOLOGICAL COLLEGE, LUBBOCK, TEXAS. ERECTED 1924
Planned as a chemical laboratory. Now used in part for other sciences.

CHEMICAL PROGRESS IN THE SOUTH

PART IV. STATISTICAL INFORMATION

PART IV

STATISTICAL INFORMATION

Foreword

J. E. Mills, National Research Council, Washington, D. C.

The South is blessed beyond any other section of the country by its temperate climate, its abundant rainfall, its long coast line, its streams and rivers, and mountains. Home surroundings and industrial sites can be made beautiful with far less effort than is necessary in other sections of the country. These things add much to the pleasure of living. Beautiful surroundings pay dividends in delight given. This asset of the South cannot be made subject to any statistical treatment, but it is an asset that should not be overlooked by any individual or by any community.

The negro population of the South introduces always a complication when industrial statistics are considered, for the negro plays at the present time almost no part in the industrial development of the South. This is not due, as many outside of the South suppose, to the wishes of the southerner, but to the negro himself. The negro does not object to hard work, but every fiber of his being seems finally to resist regular work.

Representing the value of industrial production per unit of population as 100 for the United States, the relative industrial activity of certain southern states is shown below in column two.*

	Relative industrial activity, 1927	*Per cent negro population*	*Relative industrial activity per unit of white population*
United States	100	9.9	100
Virginia	50	29.9	71
North Carolina	76	29.8	108
South Carolina	37	51.4	76
Georgia	36	41.7	62
Florida	30	34.0	45
Alabama	41	38.4	67
Mississippi	21	52.2	44
Louisiana	63	38.9	103
Texas	42	15.9	50
Oklahoma	29	7.4	31
Arkansas	18	27.0	25
Kentucky	33	9.8	37
Tennessee	47	19.3	58

The southerner, realizing that the negro plays only a small part in the industrial expansion now taking place in the South, instinctively considers this change as affecting the white population only as shown in column four.

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* E. P. Partridge, *Ind. Eng. Chem.*, **22**, 413, 1930, except as to Louisiana, Texas, and Oklahoma, for which the values were calculated by the author.

TABLE I

Statistics for 1927-1928 of Accredited Universities and Colleges in Thirteen Southern States

COMPILED FROM U. S. DEPARTMENT OF INTERIOR—OFFICE OF EDUCATION BULLETIN No. **38**, 1929

Universities and colleges marked with an asterisk are publicly controlled. "C" stands for co-educational, "W" for women, and "M" for men. The number of students given is as taken from the Bulletin referred to above and is exclusive of students in summer school, extension classes, and correspondence courses. In some colleges marked co-educational, women or men are admitted only to special courses. The value of property given includes value of libraries, scientific apparatus, machinery, furniture, and other equipment; value of grounds (including farm); value of buildings (including dormitories) and value of all other property (excluding endowment). Statistics concerning medical colleges which are part of a university are included in the university returns and are not separately shown.

		No. of students	*Value of property*	*Productive funds*	*Total receipts, exclusive of additions to endowment*
Alabama					
Alabama C. for Women, Montevallo*	W[1]	1075	$1,140,500	$582,722	$691,180
Ala. Polytechnic Inst., Auburn*	C	1614	1,916,285	253,500	1,584,111
Birmingham-Southern C., Birmingham	C	1073	1,741,500	910,068	465,337
Howard College, Birmingham	C	817	457,690	590,741	235,834
Judson College, Marion	W	298	724,902	514,398	191,077
Springhill College, Springhill	M	348	810,000	.....	118,035
Univ. of Alabama, University*	C	2823	2,090,861	1,958,989	1,061,965
Woman's C. of Ala., Montgomery	W	775	634,984	307,749	269,590

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[1] Admitted 121 men in high-school department.

Arkansas					
Hendrix College, North Little Rock	C	317	395,112	579,043	192,580
Ouachita College, Arkadelphia	C	333	389,211	540,404	161,627
Univ. of Arkansas, Fayetteville*	C	1878	2,220,000	132,667	1,304,189
Florida					
Florida S. C. for W., Tallahassee*	W[1]	1434	2,905,000	100,000	943,582
Rollins College, Winter Park	C	375	319,161	595,568	229,797
University of Florida, Gainesville*	C[2]	2077	4,948,675	325,046	2,096,464

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[1] Admitted 2 men.

[2] Admitted 15 women.

Georgia					
Agnes Scott College, Decatur	W	500	1,000,086	1,051,420	355,278
Brenau College, Gainesville	W	473	733,000	566,000	331,468
Emory University, Emory University	C	1356	4,990,362	4,142,073	870,754
Georgia Sch. of Technology, Atlanta*	M	2178	3,029,000	200,000	737,216
Ga. S. C. for Women, Milledgeville*	W	1222	1,318,000	.....	442,141

TABLE I (*Continued*)

		No. of students	*Value of property*	*Productive funds*	*Total receipts, exclusive of additions to endowment*
Ga. State Women's College, Valdosta	(Not listed)				
Mercer University, Macon	C	720	1,044,769	735,603	264,939
Shorter College for Women, Rome	W	230	488,846	. . . . .	154,701
University of Georgia, Athens*	C	1726	3,964,110	410,202	1,343,903
Wesleyan College, Macon	W	660	798,967	494,659	1,358,869
Medical College of Ga., Augusta	C	133	199,200	25,000	169,233
Kentucky					
Berea College, Berea	C	1905	3,006,612	8,894,739	1,016,741
Centre College, Danville	C	335	614,241	1,249,107	158,979
Georgetown College, Georgetown	C	340	349,097	654,624	186,454
Transylvania College, Lexington	C	338	741,225	819,302	95,692
Univ. of Kentucky, Lexington*	C	2791	3,088,799	184,078	2,216,070
Univ. of Louisville, Louisville*	C	1385	1,375,195	627,552	443,919
Louisville Coll. of Pharm., Louisville	C	88	120,000	27,900	18,803
Louisiana					
Centenary C. of La., Shreveport	C	649	542,258	651,613	(not listed)
Louisiana College, Pineville	C	575	503,178	299,975	130,596
La. Polytechnic Institute, Ruston*	C	945	1,010,075	. . . . .	398,302
La. S. U. and A. & M. C., Baton Rouge*	C	2098	6,419,414	318,213	1,594,471
Loyola University, New Orleans	C	488	3,361,000	80,000	218,604
H. Sophie Newcomb Memorial College	(Included with Tulane University)				
Southwestern La. Inst., Lafayette*	C	1281	869,500	. . . . .	535,974
Tulane U. of La., New Orleans	C	3157	5,489,473	8,982,001	1,629,747
Mississippi					
Blue Mountain C., Blue Mountain	W[1]	324	499,760	300,176	360,200
Millsaps College, Jackson	C	457	649,238	931,909	166,491
Miss. A. & M. C., A. & M. College*	M[3]	1431	2,895,555	239,788	1,707,374
Mississippi College, Clinton	C	553	473,774	698,917	203,784
Miss. State C. for Women, Columbus*	W	1374	2,572,450	156,489[4]	504,559
Miss. Women's C., Hattiesburg	W[2]	450	392,071	300,494	159,608
U. of Mississippi, University*	C	1120	2,893,100	710,153	1,966,028

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[1] Admitted 1 man.

[2] Admitted 2 men.

[3] Admitted 9 women.

[4] Figures for 1925–26.

North Carolina					
Catawba College, Salisbury	C	268	460,000	300,000	115,281
Davidson College, Davidson	M[1]	636	1,301,952	947,508	356,010
Duke University, Durham	C	1705	21,148,700	20,785,207	1,850,294
Elon College, Elon	C	400	1,226,911	520,739	126,720
Greensboro College, Greensboro	W	347	719,431	351,345	184,213
Guilford College, Guilford College	C	309	412,000	575,000	137,653
Lenoir-Rhyne College, Hickory	C	290	799,000	462,000	432,100
Meredith College, Raleigh	W	551	1,403,789	470,903	221,747
N. C. S. C. of Agr. & Eng., W. Raleigh*	M[4]	1541	4,129,085	125,000	2,097,269

TABLE I *(Continued)*

		No. of students	*Value of property*	*Productive funds*	*Total receipts, exclusive of additions to endowment*
N. C. College for Women, Greensboro*	W[3]	1564	6,074,367	.....	1,556,149
Salem College, Winston-Salem	W	357	562,704	440,206	164,624
U. of N. C., Chapel Hill*	C	2889	7,949,874	2,137,648	3,237,313
Wake Forest College, Wake Forest	M[2]	736	650,285	2,264,150	253,050

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[1] Admitted 7 women.

[2] Admitted 2 women.

[3] Admitted 2 men.

[4] Admitted 14 women.

Oklahoma

Okla. A. & M. College, Stillwater*	C	2860	3,073,365	......	2,041,598
Okla. C. for Women, Chickasha*	W	799	1,405,000	.....	170,200
Phillips University, Enid	C	678	633,743	392,740	139,820
Univ. of Oklahoma, Norman*	C	5378	4,320,853	3,200,000	2,227,983
Univ. of Tulsa, Tulsa	C	777	391,372	698,827	184,352

South Carolina

Clemson Agr. College, Clemson C.*	M	1212	2,172,400	154,440	1,586,485
Coker College, Hartsville	W	246	554,170	567,210	161,076
College of Charleston, Charleston*	C	257	475,000	422,000	75,251
Converse College, Spartanburg	W	476	1,049,213	637,487	328,360
Erskine College, Due West	C	367	244,000	300,000	83,058
Furman University, Greenville	M[1]	513	1,286,581	655,519	209,757
Limestone College, Gaffney	W	308	587,353	328,645	112,627
Presbyterian C. of S. C., Clinton	M	272	722,513	337,205	110,988
The Citadel, Charleston*	M	722	2,614,100	.....	421,335
Univ. of South Carolina, Columbia*	C	1609	2,834,704	.....	471,577
Winthrop College, Rock Hill*	W	2054	3,056,459	.....	972,503
Wofford College, Spartanburg	M[1]	479	703,278	320,009	166,718
Medical C. of State of S. C., Charleston	C[2]	153	(Not listed)		

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[1] Admitted 2 women.

[2] Statistics of 1928–29.

Tennessee

Carson and Newman C., Jefferson City	C	440	421,109	521,036	37,600
George Peabody C. for T., Nashville	(Not listed)				
Maryville College, Maryville	C	786	777,713	1,483,951	163,741
Southwestern College, Memphis	C	468	1,997,115	369,960	325,685
Tusculum College, Greenville	C	213	571,076	678,531	116,247
Univ. of Chattanooga, Chattanooga	C	393	1,283,400	1,005,600	113,053
University of the South, Sewanee	M	344	1,231,038	1,687,912	286,381
University of Tennessee, Knoxville*	C	3032	6,684,088	446,260	2,411,702
Vanderbilt University, Nashville	C	1342	5,618,099	10,777,394	1,628,139
Meharry Medical College (colored), Nashville	C	397	600,000	719,373	168,474

Texas

A. & M. C. of Texas, College Station*	M	2548	6,589,537	209,000	4,059,493
Baylor College for Women, Belton	W	1763	1,302,429	534,277	657,414
Baylor University, Waco	C	3732	1,712,100	541,000	663,803

TABLE I (*Concluded*)

		No. of students	*Value of property*	*Productive funds*	*Total receipts, exclusive of additions to endowment*
C. of Industrial Arts, Denton*	M	1702	2,432,037	.....	877,562
Incarnate Word College, San Antonio	W	657	1,928,650	.....	(not listed)
Our Lady of the Lake C., San Antonio	W	450	1,627,298	.....	152,248
Rice Institute, Houston	C	1322	3,926,100	10,500,000	973,200
Simmons University, Abilene	C	1291	680,773	491,000	310,764
Southwestern Univ., Georgetown	C	534	1,117,010	422,764	230,665
Southern Methodist U., Dallas	C	2289	4,197,345	2,277,402	833,387
Texas Christian Univ., Fort Worth	C	1366	1,023,263	45,320	670,983
Texas Technological C., Lubbock*	C	1682	1,931,023	.....	927,655
Trinity University, Waxahachie	C	459	313,124	695,032	151,895
University of Texas, Austin*	C	6308	10,491,095	21,060,521	2,911,140
Virginia					
Bridgewater College, Bridgewater	C	234	303,111	379,422	84,373
C. of Wm. and Mary, Williamsburg*	C	1288	3,110,500	332,557	1,252,998
Emory and Henry College, Emory	C	458	490,652	365,223	173,823
Hampden-Sidney C., Hampden-Sidney	M	258	546,268	167,700	97,744
Lynchburg College, Lynchburg	C	262	518,270	484,543	184,701
Randolph-Macon C. for Men, Ashland	M	263	490,930	996,382	105,322
Randolph-Macon C. for W., Lynchburg	W	854	1,528,283	1,012,667	569,193
Roanoke College, Salem	M	261	511,436	650,113	122,872
Sweet Briar College, Sweet Briar	W	451	1,013,910	411,065	452,560
University of Richmond, Richmond	C	1011	1,873,712	2,196,996	593,103
University of Virginia, University*	C	2196	3,478,434	4,061,632	1,925,745
Virginia Military Inst., Lexington*	M	713	1,602,237	103,000	927,113
Va. A. & M. C. & Poly. Inst., Blacksburg*	C	1266	3,683,380	344,312	1,983,510
Washington and Lee U., Lexington	M	909	1,651,462	1,390,047	339,396
Medical College of Va., Richmond*	C	780	1,296,595	123,311	566,127

TABLE II

Population of Principal Cities in Thirteen Southern States

Preliminary Report for 1930—Bureau of Census

City	*Population*	*City*	*Population*
New Orleans	455,792	Tulsa	141,281
Louisville	307,808	Jacksonville	129,682
Houston	289,579	Norfolk	127,808
Atlanta	266,559	Chattanooga	119,539
Dallas	260,397	Miami	110,514
Birmingham	257,657	Knoxville	105,797
San Antonio	254,562	El Paso	101,975
Memphis	252,049	Tampa	100,910
Oklahoma City	185,383	Savannah	87,714
Richmond	182,883	Charlotte	82,645
Fort Worth	160,892	Little Rock	81,657
Nashville	153,153	Shreveport	76,659

TABLE II—(*Continued*)

City	*Population*	*City*	*Population*
Winston-Salem	75,288	Galveston	53,427
Roanoke	69,096	Greensboro	53,422
Mobile	68,277	Austin	53,118
Montgomery	65,801	Waco	52,825
Covington	66,075	Durham	52,026
Charleston	62,123	Columbia	50,195
Augusta	60,204	Asheville	50,159
Beaumont	57,483	Port Arthur	50,067
Macon	53,866		

TABLE III

Area, Population, and Wealth of Thirteen Southern States*

		Population			
	Area square miles	*White 1920 census*	*Negro 1920 census*	*Total 1930*†	*Property true value 1928*
Alabama	51,998	1,447,032	900,652	2,645,297	$3,304,000,000
Arkansas	53,335	1,279,757	472,220	1,853,981	2,866,000,000
Florida	58,666	638,153	329,487	1,466,625	2,887,000,000
Georgia	59,265	1,689,114	1,206,365	2,902,443	4,421,000,000
Kentucky	40,598	2,180,560	235,938	2,623,668	3,979,000,000
Louisiana	48,506	1,096,611	700,257	2,094,496	3,847,000,000
Mississippi	46,865	853,962	935,184	2,007,979	2,464,000,000
North Carolina	52,426	1,783,779	763,407	3,170,287	5,396,000,000
Oklahoma	70,057	1,821,194	149,408	2,391,777	4,261,000,000
South Carolina	30,989	818,538	864,719	1,732,567	2,749,000,000
Tennessee	42,022	1,885,993	451,758	2,608,759	4,930,000,000
Texas	265,896	3,918,165	741,694	5,821,272	10,898,000,000
Virginia	42,627	1,617,909	690,017	2,419,471	5,637,000,000
Total	863,250	21,030,767	8,441,106	33,738,622	57,639,000,000
United States	3,026,789	94,820,915	10,463,131	122,698,190	360,062,000,000

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* These figures are taken from Blue Book of Southern Progress, 1930. Published by the *Manufacturers Record.*

† Preliminary figures—Bureau of Census.

TABLE IV

Productive Power of Thirteen Southern States*

	Manufactured products value	*Mineral products value*	*Agricultural products value*	*Gross value all products*
Alabama	$550,372,126	$69,807,000	$255,453,000	$875,632,126
Arkansas	182,750,871	45,010,000	274,541,000	502,301,871
Florida	218,790,152	15,227,000	131,804,000	365,821,152
Georgia	609,917,660	14,740,000	318,231,000	942,888,660
Kentucky	447,764,961	131,970,000	308,735,000	888,469,961
Louisiana	638,361,215	56,810,000	186,464,000	881,635,215
Mississippi	196,640,742	2,634,000	316,348,000	515,622,742
North Carolina	1,154,646,612	11,480,000	373,562,000	1,539,688,612
Oklahoma	371,718,409	486,634,000	381,556,000	1,239,908,409

TABLE IV—(*Continued*)

	Manufactured products value	*Mineral products value*	*Agricultural products value*	*Gross value all products*
South Carolina	358,334,205	4,046,000	193,485,000	555,865,205
Tennessee	614,040,524	38,789,000	301,981,000	954,810,524
Texas	1,206,579,962	378,617,000	875,840,000	2,461,036,962
Virginia	671,346,808	38,770,000	272,320,000	982,436,808
Total	7,221,264,247	1,294,534,000	4,190,320,000	12,706,118,247
United States	62,718,347,289	5,400,000,000	14,819,573,000	82,937,920,289

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* These figures are taken from Blue Book of Southern Progress, **1930.** Published by the *Manufacturers Record.*

Figures for manufacturing are for latest census year, 1927; those for mineral products are 1928 estimates, while those for agriculture are 1929 estimates.

TABLE V

Potential and Developed Southern Waterpower

(*From Blue Book of Southern Progress,* **1930**)

States	*Available* 90 per cent of time horsepower*	*Available* 50 per cent of time horsepower*	*Capacity† developed Jan. 1, 1929, horsepower*
Alabama	472,000	1,050,000	799,085
Arkansas	200,000	300,000	15,680
Florida	20,000	30,000	9,255
Georgia	572,000	958,000	543,685
Kentucky	172,000	280,000	142,255
Louisiana	1,000	2,000	.....
Mississippi	30,000	60,000	.....
North Carolina	852,000	1,160,000	814,000
Oklahoma	70,000	194,000	1,948
South Carolina	555,000	860,000	574,000
Tennessee	654,000	882,000	177,425
Texas	288,000	614,000	29,454
Virginia	459,000	812,000	140,239
Total	4,345,000	7,202,000	3,247,026
United States	38,110,000	59,166,000	13,571,530

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* Computed January 1, 1928, by the Geological Survey.

† Included only plants producing over 100 horsepower; those producing less are estimated to have an aggregate capacity of 900,000 horsepower in the United States.

TABLE VI

Summary Census of Manufactures, 1927, for Thirteen Southern States*

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*	*Horsepower*
Alabama	2355	119,093	$105,488,817	$317,493,407	$550,372,126	779,156
Arkansas	1146	40,032	35,288,168	103,815,280	182,750,871	183,041
Florida	1912	61,219	56,671,574	91,715,524	218,790,152	177,580

TABLE VI—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*	*Horsepower*
Georgia	3175	154,168	108,118,193	360,261,684	609,917,660	565,899
Kentucky	1851	74,912	83,858,607	250,632,957	447,764,961	318,755
Louisiana	1624	82,415	79,673,477	427,994,341	638,361,215	415,582
Mississippi	1333	50,569	40,734,359	105,559,493	196,640,742	214,232
North Carolina	2984	204,570	158,394,434	560,819,236	1,154,646,612	810,798
Oklahoma	1373	27,932	35,785,266	269,418,221	371,718,409	185,480
South Carolina	1059	108,992	74,477,866	206,772,453	358,334,205	478,245
Tennessee	2098	114,968	101,197,846	351,436,325	614,040,524	475,243
Texas	4065	116,763	130,408,661	842,927,286	1,206,579,962	635,455
Virginia	2432	114,918	110,377,945	346,165,769	671,346,808	503,726
Total	27,407	1,270,571	1,120,475,213	4,235,011,976	7,221,264,247	5,743,192
United States	191,866	8,349,755	10,848,802,532	35,133,136,889	62,718,347,289	38,825,681

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* From United States Department of Commerce, Census of Manufactures, 1927.

TABLE VII

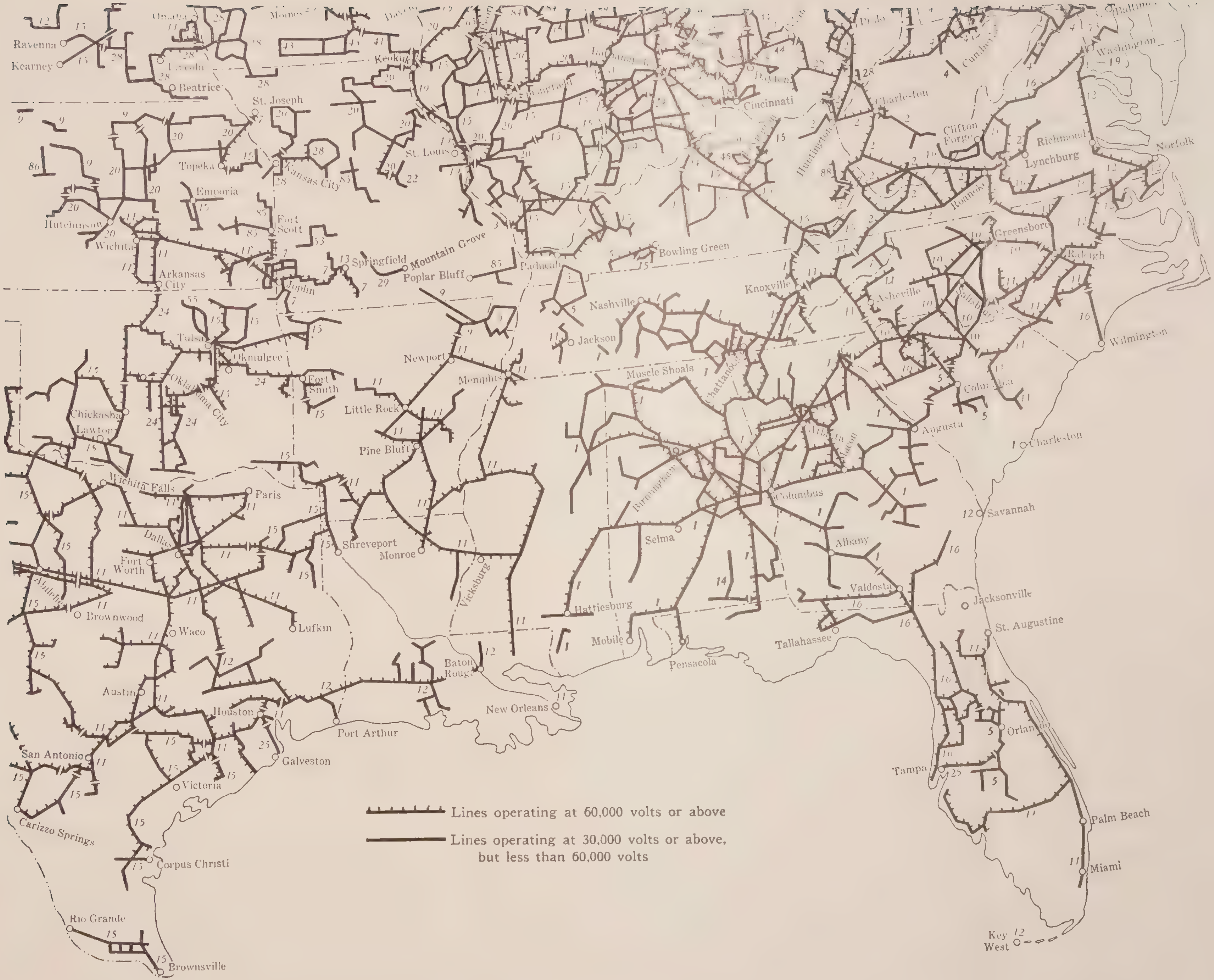
Statistics by Industries for Thirteen Southern States

Statistics by industries for thirteen southern states are given below. The data were taken from the United States Department of Commerce Census of Manufactures for the calendar year 1927. These statistics are limited to establishments reporting products of $5000 or more. Also in order to avoid disclosing the operations of individual establishments the Department of Commerce does not list establishments under each state unless there are three or more establishments reporting from a state. Since the statistics for the thirteen states covered were obtained by adding the figures given for each of the individual states, the industry will not be completely covered unless there are at least three establishments in the states concerned. Therefore with certain industries such as aluminum, paper, cement, rayon, explosives, etc., the statistics given are quite incomplete. The incomplete character of the census report when applied to the thirteen states mentioned will be realized by noting that for these states the census figures for "all other industries" show 100,570 wage earners and $771,819,554 as the value of the products.

Only those industries are listed in which three or more establishments reported from at least one of the states covered.

An asterisk after the industry indicates that more detailed information is given in the pages following.

Industries	*Wage earners (average for year)*	*Value of products*	*United States value of products*
Agricultural implements	1,059	$3,652,153	$202,732,126
Alcohol, ethyl*	270	6,292,750	33,971,150
Artificial limbs	14	78,113	3,215,591
Awnings, tents, sails, and canvas covers	892	5,999,910	47,929,352
Bags, other than paper, not made in textile mills	2,917	38,317,661	162,949,837


Lines operating at 60,000 volts or above
Lines operating at 30,000 volts or above, but less than 60,000 volts
Ravenna
Kearney
Omaha
Lincoln
Beatrice
St. Joseph
Keokuk
Topeka
Kansas City
Emporia
Hutchinson
Wichita
Fort Scott
Arkansas City
Joplin
Springfield
Mountain Grove
Poplar Bluff
St. Louis
Paducah
Bowling Green
Cincinnati
Dayton
Charleston
Huntington
Clifton Forge
Richmond
Lynchburg
Roanoke
Washington
Norfolk
Greensboro
Raleigh
Knoxville
Asheville
Nashville
Jackson
Tulsa
Okmulgee
Oklahoma City
Fort Smith
Newport
Memphis
Little Rock
Muscle Shoals
Chattanooga
Chickasha
Lawton
Pine Bluff
Wichita Falls
Paris
Dallas
Fort Worth
Shreveport
Monroe
Vicksburg
Abilene
Brownwood
Waco
Lufkin
Birmingham
Atlanta
Macon
Augusta
Columbia
Wilmington
Charleston
Columbus
Selma
Albany
Savannah
Hattiesburg
Mobile
Pensacola
Tallahassee
Valdosta
Jacksonville
St. Augustine
Baton Rouge
New Orleans
Austin
Houston
Port Arthur
Galveston
San Antonio
Victoria
Carizzo Springs
Corpus Christi
Rio Grande
Brownsville
Orlando
Tampa
Palm Beach
Miami
Key West

Courtesy of The Annalist, Times Square, New York

FIGURE 21.—HIGH-TENSION LINES IN THE SOUTH

TABLE VII—(*Continued*)

Industries	*Wage earners (average for year)*	*Value of products*	*United States value of products*
Baskets and rattan and willow ware, not including furniture	3,110	5,288,894	21,728,900
Belting, leather	38	739,689	27,265,752
Beverages*	7,831	68,253,968	242,694,456
Bone black, carbon black, and lampblack*	1,099	10,494,926	14,261,775
Bookbinding and blank-book making	295	992,461	87,327,392
Boots and shoes, other than rubber	4,094	16,200,557	944,714,463
Boxes, cigar, wooden	645	1,760,917	12,908,739
Boxes, paper and other, not elsewhere classified	2,514	10,831,093	306,555,062
Boxes, wooden, except cigar boxes	9,447	29,303,951	133,992,877
Brass, bronze, and other non-ferrous alloys, and manufactures of these alloys and of copper, not specifically classified	467	3,322,535	519,892,352
Bread and other bakery products	18,757	128,635,053	1,394,700,224
Brooms	841	3,394,172	18,444,912
Butter	2,160	49,986,975	739,010,876
Cheese	3	34,787	118,447,757
Buttons	98	210,395	29,130,168
Canning and preserving, fish, crabs, shrimps, oysters, and clams*	4,472	8,799,090	65,082,187
Canning and preserving, fruits and vegetables; pickles, jellies, preserves, and sauces*	6,233	23,368,336	572,345,862
Car and general construction and repairs, electric-railroad repair shops	2,518	5,539,282	84,504,448
Car and general construction and repairs, steam-railroad repair shops	90,332	250,118,320	1,205,190,710
Carriage, wagon, sleigh, and sled materials	293	1,282,315	3,040,948
Carriages, wagons, sleighs, and sleds	511	2,006,102	19,422,235
Cars, electric and steam-railroad, not built in railroad repair shops	259	982,819	312,508,598
Caskets, coffins, burial cases, and morticians' goods	1,561	8,232,349	74,890,850
Cast-iron pipe*	12,379	48,271,550	95,088,622
Cement*	1,817	17,800,979	293,565,293
Cereal preparations	80	3,312,208	155,563,286
Chemicals, not elsewhere classified*	2,128	18,016,374	548,535,935
Cigars and cigarettes*	36,118	572,807,494	965,523,702
Clay products (other than pottery) and non-clay refractories*	17,480	41,206,596	319,907,843
Cleaning and polishing preparations*	30	271,116	41,234,466
Clothing (except work clothing), men's, youths', and boys', not elsewhere classified	6,288	20,343,006	932,181,718
Clothing, women's, not elsewhere classified	2,129	6,999,677	1,494,401,044
Clothing, work (except shirts), men's	13,758	40,652,149	147,289,025
Coffee and spice, roasting and grinding	1,322	55,617,312	384,281,306
Coke, not including gas-house coke*	2,155	28,402,620	382,012,617
Compressed and liquefied gases*	467	6,814,122	50,547,395

TABLE VII—(*Continued*)

Industries	*Wage earners (average for year)*	*Value of products*	*United States value of products*
Concrete products*	2,783	11,164,600	93,259,206
Confectionery*	6,189	35,327,214	391,927,343
Cooperage	2,786	11,605,856	66,947,424
Copper, tin, and sheet-iron work, including galvanized-iron work, not elsewhere classified	2,428	20,704,203	191,128,636
Cordage and twine*	3,034	11,754,185	89,172,495
Cotton goods*	277,659	884,639,719	1,567,400,612
Cotton small wares*	161	856,515	64,819,965
Dental goods, including dental-laboratory work	87	552,353	42,695,252
Druggists' preparations*	222	2,632,519	110,309,139
Dyeing and finishing textiles*	5,030	34,949,268	406,047,372
Electrical machinery, apparatus, and supplies	1,121	6,519,313	1,637,307,035
Engraving, steel and copperplate, and plate printing	383	1,715,625	39,071,105
Excelsior	206	496,170	4,821,098
Explosives*	43	587,849	72,489,668
Fancy and miscellaneous articles, not elsewhere classified	37	142,413	83,006,431
Feeds, prepared, for animals and fowls	1,442	49,675,760	299,792,642
Fertilizers*	11,628	105,415,387	190,384,890
Flavoring extracts and flavoring sirups*	297	16,189,856	107,219,395
Flour and other grain-mill products	5,824	181,778,150	1,148,760,360
Food preparations, not elsewhere classified	649	7,698,834	166,964,672
Foundry and machine-shop products, not elsewhere classified	23,377	120,799,361	2,259,794,443
Furnishing goods, men's, not elsewhere classified	70	356,410	145,474,143
Furniture, including store and office fixtures	31,530	117,684,332	879,706,306
Gas manufactured, illuminating and heating*	3,552	27,991,799	516,705,170
Glass*	1,445	6,656,773	282,394,330
Glass cutting, staining, and ornamenting	47	285,535	22,327,581
Grease and tallow, not including lubricating greases*	145	1,120,070	56,279,958
Hand stamps and stencils and brands	136	617,061	14,155,607
Hardware, not elsewhere classified	288	1,157,160	208,253,586
Hats and caps, except felt and straw	211	1,243,347	41,213,965
Hats, fur-felt	101	499,755	99,299,648
House-furnishing goods, not elsewhere classified	70	399,113	87,676,606
Ice cream	3,229	37,752,022	301,644,991
Ice, manufactured	8,559	101,518,185	184,794,988
Iron and steel: Blast furnaces*	4,496	52,993,383	708,904,238
Iron and steel: Steel works and rolling mills*	12,015	109,474,435	2,779,840,238
Jewelry	170	640,045	164,865,057
Jute goods*	60	208,424	23,185,997
Knit goods*	48,354	145,417,430	816,620,494
Lard substitutes and vegetable cooking oils*	1,255	66,374,936	148,468,076
Leather: Tanned, curried, and finished*	3,504	36,371,706	494,255,838

TABLE VII—(*Continued*)

Industries	*Wage earners (average for year)*	*Value of products*	*United States value of products*
Lime*	2,385	6,258,748	41,587,458
Lithographing	317	1,572,621	97,050,124
Lumber and timber products, not elsewhere classified	215,098	519,460,177	1,214,645,683
Macaroni, spaghetti, vermicelli, and noodles	243	1,813,604	45,353,200
Marble, granite, slate, and other stone products	7,713	28,864,494	201,181,281
Mattresses and bed springs, not elsewhere classified	2,838	18,461,388	98,834,558
Millinery	931	3,333,068	209,494,828
Minerals and earths, ground or otherwise treated	1,016	4,579,852	41,260,461
Mirrors, framed and unframed	414	4,024,482	31,424,943
Models and patterns, not including paper patterns	5	35,849	23,494,992
Motor-vehicle bodies and motor-vehicle parts	3,137	13,665,801	1,151,426,365
Oil, cake, and meal, cottonseed*	17,523	253,345,934	276,338,488
Paints and varnishes*	1,019	18,885,544	519,009,842
Paper*	3,244	37,265,696	919,891,465
Pulp (wood and other fiber)*	2,753	21,640,853	218,198,201
Paper goods, not elsewhere classified*	28	318,339	140,947,815
Patent and proprietary medicines and compounds*	1,137	19,319,718	278,242,929
Paving materials, other than brick or granite*	4,749	17,848,523	103,249,144
Peanuts, walnuts, and other nuts, processed*	3,183	29,416,947	55,949,802
Perfumes, cosmetics, and other toilet preparations*	549	6,709,980	161,245,659
Petroleum refining*	24,629	742,001,560	2,142,648,503
Photo-engraving, not done in printing establishments	630	3,782,869	69,207,376
Planing-mill products, not made in planing mills connected with sawmills	26,375	138,150,967	581,633,737
Pottery, including porcelain ware*	170	560,140	110,597,338
Printing and publishing, book and job	12,247	62,017,705	906,468,767
Printing and publishing, newspaper and periodical	16,109	148,469,415	1,585,075,512
Rayon	See Chapter XIX		109,888,336
Rice cleaning and polishing	857	30,870,520	54,129,646
Rubber goods, other than tires, inner tubes, boots, and shoes	140	577,507	230,781,250
Saddlery and harness	1,073	6,887,099	27,356,244
Salt*	843	3,705,883	34,329,236
Sand-lime brick	25	74,898	3,616,456
Sausage, meat puddings, headcheese, etc., and sausage casings, not made in slaughtering and meat-packing establishments*	121	1,666,637	81,548,299
Ship and boat building, steel and wooden, including repair work	8,353	29,349,746	211,127,067

TABLE VII—(*Concluded*)

Industries	*Wage earners (average for year)*	*Value of products*	*United States value of products*
Shirts	3,096	10,844,803	241,649,939
Signs and advertising novelties	907	4,964,881	98,481,024
Silk manufactures	1,525	8,208,630	750,123,705
Slaughtering and meat packing, wholesale*	6,670	139,826,423	3,057,215,718
Smelting and refining, zinc*	1,717	15,207,105	108,297,975
Sporting and athletic goods, not including firearms and ammunition	181	534,466	44,942,778
Stoves and ranges (other than electric) and warm-air furnaces	4,330	16,777,534	258,285,829
Structural and ornamental iron and steel work, not made in rolling mills	4,737	36,560,931	440,376,360
Sugar, cane, not including products of refineries*	971	8,009,120	8,009,120
Sugar refining, cane*	2,069	82,574,116	597,445,632
Tanning materials, natural dyestuffs, mordants and assistants, and sizes*	1,059	6,556,232	35,677,033
Textile machinery and parts	658	3,534,008	116,921,130
Tin cans and other tinware, not elsewhere classified	414	3,280,678	253,478,691
Tobacco, chewing and smoking, and snuff*	4,764	54,233,339	198,244,677
Tools, not including edge tools, machine tools, files, or saws	201	991,166	117,430,624
Trunks, suitcases, and bags	1,289	5,703,563	59,958,681
Turpentine and rosin*	37,533	39,415,689	39,902,971
Upholstering materials, not elsewhere classified	131	820,525	9,672,806
Vinegar and cider*	259	1,558,405	10,755,246
Wall plaster, wall board, and floor composition	547	4,186,731	83,856,008
Window and door screens and weather strips	170	907,512	22,643,361
Window shades and fixtures	48	773,708	37,081,937
Wirework, not elsewhere classified	75	347,223	128,535,783
Wood distillation and charcoal manufacture*	567	2,863,666	27,630,487
Wood preserving*	5,322	72,331,410	184,557,640
Wood, turned and shaped, not elsewhere classified	2,828	9,156,444	42,128,173
Woolen goods*	4,254	16,211,400	301,308,743
All other industries	100,570	771,819,554	

TABLE VIII

The Textile Industry in the South

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Cotton Goods					
Alabama	68	24,825	$15,927,634	$49,850,441	$80,833,617
Arkansas	3	310	206,724	576,443	949,657
Georgia	139	56,607	36,908,790	106,882,283	180,509,344

TABLE VIII—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Kentucky	4	1,100	827,051	2,363,227	3,834,451
Mississippi	14	2,761	1,524,003	3,682,231	6,563,051
North Carolina	374	95,786	66,149,690	184,509,360	310,299,158
South Carolina	163	75,069	49,383,478	135,085,027	231,272,599
Tennessee	21	7,211	4,777,869	13,589,259	21,956,617
Texas	26	5,564	4,097,506	11,675,491	21,125,992
Virginia	11	8,426	7,057,919	14,177,760	27,295,233
Total	823	277,659	186,860,664	522,391,522	884,639,719
Knit Goods					
Alabama	13	2,026	1,036,350	4,358,917	5,958,343
Georgia	37	6,025	3,376,352	9,493,768	16,760,900
Kentucky	7	1,173	661,980	1,220,821	2,593,548
Louisiana	4	837	467,831	1,045,754	1,812,055
North Carolina	128	17,427	11,961,326	37,370,779	61,365,806
South Carolina	11	1,084	586,526	1,658,882	3,016,986
Tennessee	59	16,542	10,436,628	25,613,398	44,559,667
Texas	4	118	75,259	142,858	295,320
Virginia	21	3,122	1,879,849	5,733,519	9,054,805
Total	284	48,354	30,482,101	86,638,696	145,417,430
Cotton Small Wares					
North Carolina	9	161	171,694	420,960	856,515
Woolen Goods					
Georgia	3	766	655,949	1,834,429	2,875,779
North Carolina	6	1,156	1,028,079	3,317,912	5,505,489
Tennessee	9	1,583	1,011,465	2,537,604	4,285,869
Virginia	6	749	737,823	1,520,059	3,544,263
Total	24	4,254	3,433,316	9,210,004	16,211,400
Silk Manufactures					
Virginia	14	1,525	1,258,986	4,339,308	8,208,630
Jute Goods					
Georgia	3	60	31,424	135,702	208,424
Cordage and Twine					
Alabama	5	702	499,001	1,551,643	2,411,563
Georgia	3	110	67,638	276,328	415,394
Kentucky	6	766	508,261	1,330,732	2,407,171
North Carolina	9	1,456	915,094	4,113,524	6,520,057
Total	23	3,034	1,989,994	7,272,227	11,754,185

TABLE VIII—(*Concluded*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Dyeing and Finishing Textiles					
North Carolina	16	2,545	2,228,412	13,381,416	18,996,189
South Carolina	7	1,302	1,134,973	3,385,877	7,162,721
Tennessee	6	1,183	1,001,535	5,305,918	8,790,358
Total	29	5,030	4,364,920	22,073,211	34,949,268

TABLE IX

The Tobacco Industry

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Cigars and Cigarettes					
Alabama	6	38	$28,147	$31,289	$93,872
Florida	87	11,164	12,323,259	14,860,835	39,817,657
Georgia	20	677	257,965	432,583	868,609
Kentucky	19	1,933	980,351	3,009,670	8,886,409
Louisiana	15	1,440	1,040,537	2,057,638	4,159,673
North Carolina	14	14,081	11,582,745	117,565,177	392,050,130
Oklahoma	3	23	11,506	19,990	42,903
Virginia	15	6,762	4,812,071	41,678,524	126,888,241
Total	179	36,118	31,036,581	179,655,706	572,807,494
Tobacco, Chewing and Smoking, and Snuff					
Kentucky	19	1,955	1,369,318	7,883,996	20,047,231
Tennessee	10	978	726,543	9,218,546	16,207,652
Virginia	7	1,831	1,115,286	9,259,113	17,978,456
Total	36	4,764	3,211,147	26,361,655	54,233,339

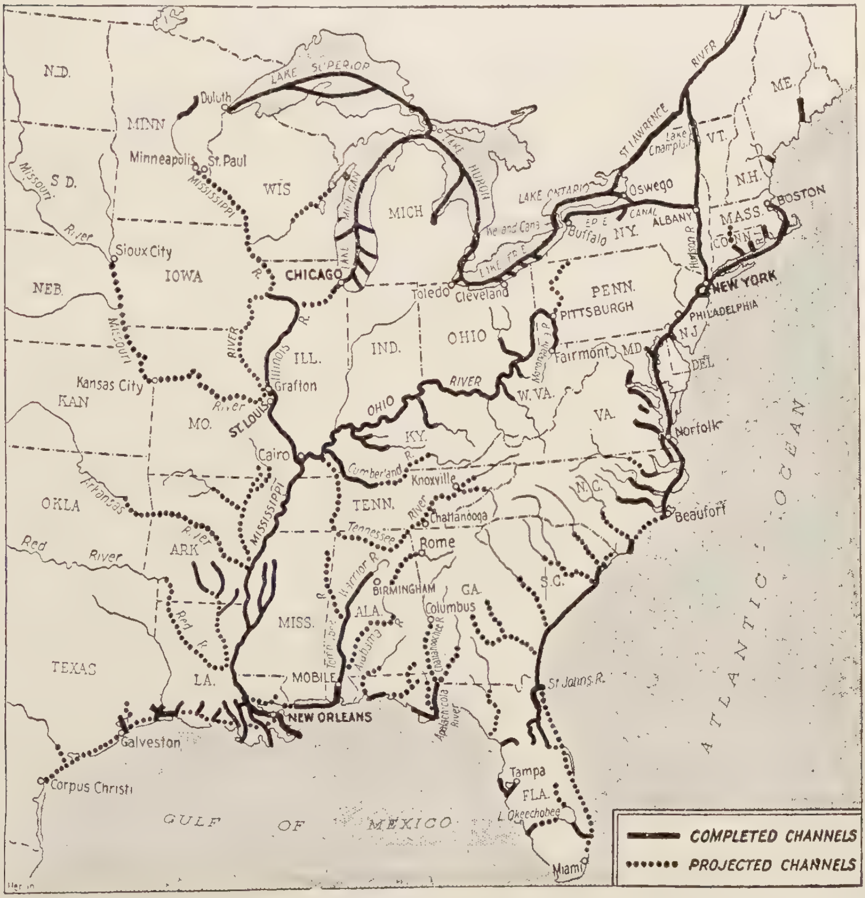
TABLE X

Slaughtering and Meat Packing

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Slaughtering and Meat Packing, Wholesale					
Alabama	8	327	$401,393	$4,316,451	$5,413,430
Florida	6	141	147,831	1,593,338	2,028,992
Kentucky	21	826	1,045,181	15,735,605	18,375,818
Louisiana	9	330	357,308	2,341,304	3,425,195
North Carolina	7	89	79,661	1,627,734	1,852,322
Tennessee	13	728	809,539	12,512,926	14,612,429
Texas	24	3,670	4,167,654	72,366,067	84,585,133
Virginia	26	559	552,397	8,086,561	9,533,104
Total	114	6,670	7,560,964	118,579,986	139,826,423

TABLE X—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Sausages, Meat Puddings, Headcheese, etc., and Sausage Casings, Not Made in Slaughtering and Meat-Packing Establishments					
Georgia	7	55	48,852	460,146	602,268
Louisiana	5	26	29,783	415,171	552,225
Tennessee	5	16	21,192	142,611	189,518
Texas	5	24	26,462	238,375	322,626
Total	22	121	126,289	1,256,303	1,666,637


N.D.
MINN
Duluth
LAKE SUPERIOR
Minneapolis
St. Paul
S D.
Missouri River
WIS
MISSISSIPPI
MICH
LAKE MICHIGAN
LAKE HURON
ST LAWRENCE
RIVER
ME.
Lake Champlain
VT.
N.H.
LAKE ONTARIO
Oswego
ERIE CANAL
ALBANY
Hudson R.
MASS.
BOSTON
CONN.
R.I.
Buffalo
N.Y.
Welland Canal
LAKE ERIE
Sioux City
IOWA
NEB.
CHICAGO
Toledo
Cleveland
PENN.
PITTSBURGH
NEW YORK
PHILADELPHIA
N.J.
DEL.
Missouri
RIVER
Illinois R.
ILL.
IND.
OHIO
Monongahela R.
Fairmont
MD.
Kansas City
KAN
Grafton
RIVER
W. VA.
MO.
River
ST. LOUIS
OHIO
VA.
Norfolk
KY.
Cairo
Cumberland R.
Knoxville
N.C.
OKLA
Arkansas River
TENN.
River
Chattanooga
Beaufort
Red River
ARK
MISSISSIPPI
Tennessee
Rome
Warrior R.
BIRMINGHAM
GA.
S.C.
Red R.
MISS.
ALA.
Columbus
Alabama R.
Chattahoochee R.
Tombigbee R.
TEXAS
LA.
MOBILE
St. Johns R.
NEW ORLEANS
Apalachicola River
Galveston
Corpus Christi
Tampa
FLA.
L. Okeechobee
Miami
GULF OF MEXICO
ATLANTIC OCEAN
COMPLETED CHANNELS
PROJECTED CHANNELS

Reproduced from the New York Times, Sunday, May 18, 1930

FIGURE 22.—THE WATERWAYS OF THE UNITED STATES EAST OF THE ROCKY MOUNTAINS

TABLE XI

Leather: Tanned, Curried, and Finished

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Kentucky	7	473	$512,678	$3,134,350	$4,636,381
North Carolina	11	1,342	1,237,242	12,128,432	16,405,352
Tennessee	7	830	651,153	3,935,815	5,037,436
Virginia	9	859	775,100	7,468,183	10,292,537
Total	34	3,504	3,176,173	26,666,780	36,371,706

TABLE XII

Canning and Preserving

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Fish, Crabs, Shrimps, Oysters, and Clams					
Alabama	4	268	$141,290	$348,751	$714,281
Florida	10	261	101,243	483,635	840,657
Georgia	9	407	94,280	451,003	681,202
Louisiana	24	1,188	256,982	1,519,928	2,279,617
Mississippi	18	940	355,767	1,156,390	2,144,553
North Carolina	5	83	30,315	86,631	151,876
South Carolina	9	836	215,059	359,225	905,663
Texas	4	272	158,258	252,384	500,802
Virginia	12	217	111,612	366,086	580,439
Total	95	4,472	1,464,806	5,024,033	8,799,090
Fruits and Vegetables; Pickles, Jellies, Preserves, and Sauces					
Alabama	5	121	65,541	523,072	737,626
Arkansas	56	929	316,018	1,319,831	2,142,078
Florida	18	639	388,813	1,134,332	2,313,998
Georgia	15	396	130,559	865,589	1,519,940
Kentucky	28	946	577,516	3,242,299	5,171,670
Louisiana	15	183	91,940	658,911	1,193,665
Mississippi	10	284	91,384	439,552	643,908
North Carolina	4	34	18,638	72,938	127,936
Oklahoma	7	84	44,911	219,330	350,882
Tennessee	44	882	253,479	1,501,470	2,139,991
Texas	38	555	260,995	1,656,188	2,776,018
Virginia	115	1,180	481,093	2,932,259	4,250,624
Total	355	6,233	2,720,887	14,565,771	23,368,336

TABLE XIII

Sugar and Sirup Industry

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Sugar Cane, Not Including Products of Refineries					
Louisiana	53	971	$639,154	$5,830,411	$8,009,120
Sugar Refining, Cane					
Louisiana	4	2,069	1,867,371	78,109,480	82,574,116

TABLE XIV

Oils, Fats, and Related Products

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Oil, Cake, and Meal, Cottonseed					
Alabama	35	1,274	$898,666	$11,648,375	$14,662,794
Arkansas	30	1,348	1,081,940	13,615,547	17,268,695
Georgia	54	2,143	1,504,043	23,190,695	27,998,981
Louisiana	22	697	530,131	18,221,768	21,338,810
Mississippi	44	2,238	1,596,395	22,450,012	27,978,008
North Carolina	53	1,418	1,067,922	13,962,245	17,612,879
Oklahoma	45	1,226	1,111,099	14,647,421	20,295,804
South Carolina	41	1,126	652,667	9,985,170	12,608,931
Tennessee	21	1,378	949,477	11,756,280	15,256,533
Texas	175	4,675	3,903,169	61,937,294	78,324,499
Total	520	17,523	13,295,509	201,414,807	253,345,934
Lard Substitutes and Vegetable Cooking Oils					
Georgia	4	500	339,190	20,644,124	22,011,424
Tennessee	5	419	417,573	23,207,989	25,693,637
Texas	7	336	378,030	16,677,454	18,669,875
Total	16	1,255	1,134,793	60,529,567	66,374,936
Grease and Tallow, Not Including Lubricating Greases					
Virginia	3	145	163,500	770,218	1,120,070

TABLE XV

Peanuts, Walnuts, and Other Nuts, Processed

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	10	265	$83,736	$1,921,554	$2,091,667
Georgia	22	622	205,411	5,137,444	5,835,997
North Carolina	9	372	127,078	3,335,637	3,833,673

TABLE XV—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Texas	13	709	367,497	2,539,826	3,423,165
Virginia	24	1,215	595,142	12,102,651	14,232,445
Total	78	3,183	1,378,864	25,037,112	29,416,947

TABLE XVI

Confectionery

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	15	182	$129,741	$504,097	$878,185
Arkansas	5	105	74,079	226,779	444,270
Florida	9	48	28,592	107,289	186,981
Georgia	26	1,126	677,293	3,087,973	5,697,972
Kentucky	18	431	282,670	1,186,894	1,881,521
Louisiana	17	431	296,128	1,177,613	2,127,103
Mississippi	6	99	71,043	262,396	433,665
North Carolina	16	221	169,074	763,347	1,277,884
Oklahoma	13	105	86,810	299,258	549,931
South Carolina	7	20	17,569	71,347	134,884
Tennessee	20	900	649,292	3,206,315	5,203,785
Texas	58	976	726,830	2,978,810	5,734,018
Virginia	20	1,545	924,907	8,169,125	10,777,015
Total	230	6,189	4,134,028	22,041,243	35,327,214

TABLE XVII

Beverages

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	103	580	$483,293	$2,272,834	$5,013,629
Arkansas	65	309	326,321	954,041	2,356,303
Florida	124	655	803,897	2,647,939	5,810,183
Georgia	142	807	778,039	3,191,234	7,684,878
Kentucky	79	361	472,140	1,530,875	3,999,916
Louisiana	59	586	593,607	2,130,726	5,555,813
Mississippi	92	548	477,938	1,934,637	4,555,128
North Carolina	161	852	945,954	3,577;425	8,440,104
Oklahoma	68	278	272,893	804,102	1,935,926
South Carolina	88	434	406,409	1,390,748	3,186,308
Tennessee	79	632	652,013	1,916,853	4,874,911
Texas	272	1,277	1,364,489	4,131,399	10,063,715
Virginia	99	512	546,512	2,167,830	4,777,154
Total	1431	7,831	8,123,505	28,650,643	68,253,968

TABLE XVIII

Chemical Industries from Wood Products

	Number of establishments	Wage earners (average for year)	Wages	Cost of materials, supplies, containers for products, fuel, and power	Value of products
Turpentine and Rosin					
Alabama	113	2,870	$1,290,386	$997,243	$2,899,579
Florida	343	13,237	6,211,546	3,670,956	13,499,130
Georgia	614	17,453	7,345,068	5,797,649	18,065,937
Louisiana	13	1,145	561,289	304,786	1,457,334
Mississippi	28	1,931	982,757	874,675	2,548,886
South Carolina	32	897	366,867	357,618	944,823
Total	1143	37,533	16,757,913	12,002,927	39,415,689
Tanning Materials, Natural Dyestuffs, Mordants and Assistants, and Sizes					
Georgia	5	46	36,589	265,048	437,266
North Carolina	7	234	156,927	874,304	1,278,064
Tennessee	6	315	259,611	1,061,356	1,526,105
Virginia	13	464	447,976	2,193,321	3,314,797
Total	31	1,059	901,103	4,394,029	6,556,232
Wood Distillation and Charcoal Manufacture					
Tennessee	3	567	447,262	1,331,583	2,863,666
Wood Preserving					
Alabama	6	349	423,120	4,198,848	6,142,371
Georgia	6	447	405,094	3,641,680	5,314,090
Kentucky	3	377	507,732	7,167,209	8,782,876
Louisiana	10	798	628,157	7,854,729	10,272,130
Mississippi	6	692	670,622	7,139,426	9,619,268
Tennessee	4	214	194,630	1,743,354	2,247,736
Texas	9	1,962	2,049,349	16,776,175	23,382,846
Virginia	9	483	511,995	4,572,974	6,570,093
Total	53	5,322	5,390,699	53,094,395	72,331,410
Paper					
Louisiana	9	1,245	1,478,399	9,591,116	15,518,937
Tennessee	3	243	267,077	1,523,894	2,265,719
Virginia	9	1,756	1,926,860	13,770,655	19,481,040
Total	21	3,244	3,672,336	24,885,665	37,265,696
Paper Goods, Not Elsewhere Classified					
Tennessee	4	28	40,939	207,800	318,339
Pulp (Wood and Other Fiber)					
Louisiana	7	963	1,238,373	3,974,174	7,348,812
Tennessee	4	364	360,103	1,963,730	3,047,402
Virginia	8	1,426	1,252,264	7,545,092	11,244,639
Total	19	2,753	2,850,740	13,482,996	21,640,853

TABLE XIX

Fertilizers

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	55	1,065	$772,873	$7,818,014	$9,497,502
Arkansas	5	89	55,593	754,088	910,628
Florida	24	1,048	956,408	9,253,239	14,807,376
Georgia	114	2,509	1,621,564	17,389,464	22,093,903
Louisiana	11	476	442,243	3,013,931	4,142,380
Mississippi	11	307	279,321	2,017,865	2,792,355
North Carolina	84	1,850	1,532,363	14,027,493	18,423,536
South Carolina	49	1,563	1,136,955	9,405,316	11,739,872
Tennessee	9	602	486,187	3,557,034	4,923,651
Texas	6	79	74,819	555,021	811,408
Virginia	44	2,040	1,705,609	11,291,137	15,272,776
Total	412	11,628	9,063,935	79,082,602	105,415,387

TABLE XX

The Manufacture of Gases

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Compressed and Liquefied Gases					
Alabama	6	43	$62,782	$120,620	$713,619
Florida	4	12	15,325	19,559	123,761
Georgia	7	76	71,642	235,274	1,059,635
Kentucky	5	19	30,670	127,397	311,864
Louisiana	5	62	71,339	210,296	977,925
Tennessee	6	30	46,142	52,080	412,683
Texas	16	103	138,645	498,053	1,879,115
Virginia	10	122	172,416	272,478	1,335,520
Total	59	467	608,961	1,535,757	6,814,122
Gas, Manufactured, Illuminating, and Heating					
Alabama	9	304	285,379	613,045	1,339,438
Florida	19	652	833,232	1,772,198	5,286,948
Georgia	15	619	576,677	1,862,906	5,122,730
Kentucky	9	73	69,277	198,497	534,024
Mississippi	8	142	152,788	318,216	787,198
North Carolina	23	342	381,388	1,295,718	3,104,253
South Carolina	8	181	187,233	639,133	1,596,987
Tennessee	7	579	594,910	973,358	3,352,310
Texas	6	173	215,468	578,624	1,773,029
Virginia	14	487	626,707	1,668,449	5,094,882
Total	118	3,552	3,923,059	9,920,144	27,991,799

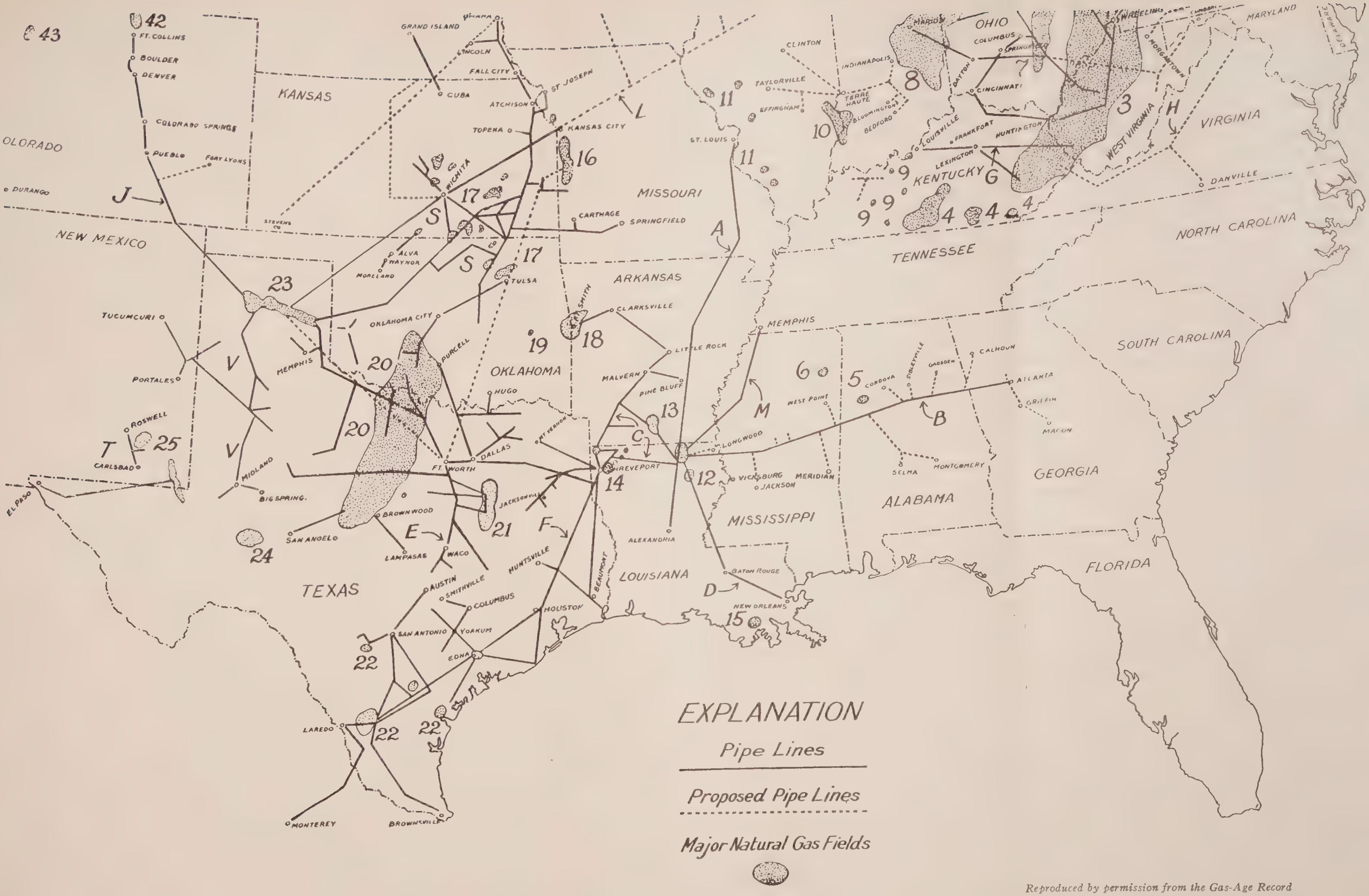

EXPLANATION
Pipe Lines
Proposed Pipe Lines
Major Natural Gas Fields
KANSAS
OLORADO
NEW MEXICO
MISSOURI
ARKANSAS
OKLAHOMA
TEXAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
OHIO
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
MARYLAND
DELAWARE
FT. COLLINS
BOULDER
DENVER
COLORADO SPRINGS
PUEBLO
FORT LYONS
DURANGO
GRAND ISLAND
LINCOLN
FALL CITY
CUBA
ATCHISON
ST JOSEPH
TOPEKA
KANSAS CITY
WICHITA
CARTHAGE
SPRINGFIELD
ST. LOUIS
CLINTON
TAYLORVILLE
EFFINGHAM
INDIANAPOLIS
TERRE HAUTE
BLOOMINGTON
BEDFORD
LOUISVILLE
FRANKFORT
LEXINGTON
HUNTINGTON
DAYTON
COLUMBUS
SPRINGFIELD
CINCINNATI
MARION
WHEELING
MORGANTOWN
DANVILLE
STEVENS
ALVA
WAYNOKA
MORELAND
TULSA
OKLAHOMA CITY
PURCELL
HUGO
FT. SMITH
CLARKSVILLE
LITTLE ROCK
MALVERN
PINE BLUFF
MEMPHIS
TUCUMCARI
PORTALES
ROSWELL
CARLSBAD
MIDLAND
BIG SPRING.
EL PASO
MEMPHIS
FT. WORTH
DALLAS
MT. VERNON
SHREVEPORT
JACKSONVILLE
BROWNWOOD
SAN ANGELO
LAMPASAS
WACO
HUNTSVILLE
BEAUMONT
ALEXANDRIA
AUSTIN
SMITHVILLE
COLUMBUS
HOUSTON
SAN ANTONIO
YOAKUM
EDNA
LAREDO
MONTEREY
BROWNSVILLE
BATON ROUGE
NEW ORLEANS
LONGWOOD
VICKSBURG
JACKSON
MERIDIAN
WEST POINT
CORDOVA
SYLACAUGA
GADSDEN
CALHOUN
ATLANTA
GRIFFIN
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FIGURE 23.—NATURAL GAS PIPE LINES IN THE SOUTHERN STATES

Natural Gas Areas: 3, Appalachian; 4, So. Central Kentucky; 5, Fayette; 6, Amory; 7, Central Ohio; 8, Lima; 9, Western Kentucky; 10, Southern Illinois; 11, Western Illinois; 12, Monroe; 13, Southern Arkansas; 14, N. W. La.-N. W. Texas; 15, Terre Bonne; 16, Western Missouri; 17, N. E. Oklahoma-Kansas; 18, Ft. Smith-Poteau; 19, Quinton; 20, No. Central Texas, Southern Oklahoma; 21, Balcones; 22, South Texas; 23, Texas Panhandle; 24, West Texas; 25, Southeast New Mexico. *Companies Controlling Natural Gas Trunk Lines:* A, Mississippi River Fuel Corporation; B, Southern Natural Gas Company; C, Arkansas Natural Gas Company; D, Interstate Natural Gas Company; E, Lone Star Gas Company; F, United Gas Company; G, Louisville Gas and Electric Company; H, Columbia Gas and Electric Company; J, Colorado Interstate Gas Company; L, Central States Natural Gas Company; M, Memphis Natural Gas Company; S, Cities Service Company; T, El Paso Natural Gas Company; V, West Texas Gas Company.

TABLE XXI

The Ceramic Industry

	Number of establishments	Wage earners (average for year)	Wages	Cost of materials, supplies, containers for products, fuel, and power	Value of products
Clay Products (Other than Pottery) and Non-Clay Refractories					
Alabama	37	2,065	$1,659,562	$1,884,886	$5,337,356
Arkansas	12	574	478,007	400,193	1,286,676
Florida	12	210	154,195	167,562	479,915
Georgia	30	2,188	1,536,185	1,761,670	4,851,497
Kentucky	38	2,742	2,687,874	2,450,839	7,366,095
Louisiana	11	216	152,836	177,987	441,746
Mississippi	22	604	365,088	307,782	1,146,472
North Carolina	60	1,661	1,194,642	1,446,274	3,816,463
Oklahoma	19	743	716,455	661,834	1,693,669
South Carolina	22	923	579,784	719,835	1,880,232
Tennessee	31	1,717	1,307,916	1,044,602	3,751,344
Texas	57	2,451	1,920,702	2,017,900	6,225,831
Virginia	43	1,386	1,160,288	930,583	2,929,300
Total	394	17,480	13,913,534	13,971,947	41,206,596
Pottery, Including Porcelain Ware					
Kentucky	3	79	80,469	49,170	323,035
North Carolina	4	9	8,730	5,485	25,192
Texas	8	82	61,311	51,566	211,913
Total	15	170	150,510	106,221	560,140
Glass					
Oklahoma	11	1,156	1,317,866	2,395,766	4,838,257
Texas	3	289	396,786	822,585	1,818,516
Total	14	1,445	1,714,652	3,218,351	6,656,773

TABLE XXII

Concrete, Lime, and Cement Products

	Number of establishments	Wage earners (average for year)	Wages	Cost of materials, supplies, containers for products, fuel, and power	Value of products
Concrete Products					
Alabama	18	266	$263,885	$425,122	$1,192,868
Florida	51	508	636,237	1,065,278	2,264,314
Georgia	19	157	132,013	258,689	669,989
Kentucky	23	115	139,254	260,032	621,845
Louisiana	14	172	157,114	261,708	683,329
Mississippi	8	69	58,102	59,472	171,192
North Carolina	21	178	151,359	283,579	660,432
Oklahoma	11	62	66,220	129,845	308,237

TABLE XXII—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
South Carolina	6	54	41,487	98,522	250,143
Tennessee	19	232	219,588	364,574	956,349
Texas	55	691	736,381	858,906	2,443,597
Virginia	23	279	258,193	307,488	942,305
Total	268	2,783	2,859,833	4,373,215	11,164,600
Lime					
Alabama	10	571	410,615	841,524	1,508,109
Arkansas	3	246	98,251	168,077	379,611
Tennessee	9	486	399,621	454,180	1,305,170
Texas	4	404	337,113	493,397	1,160,687
Virginia	22	678	606,938	799,623	1,905,171
Total	48	2,385	1,852,538	2,756,801	6,258,748
Cement					
Tennessee	5	835	975,309	3,100,502	7,222,862
Texas	7	982	1,212,784	4,033,596	10,578,117
Total	12	1,817	2,188,093	7,134,098	17,800,979

TABLE XXIII

Paving Materials, Other than Brick or Granite

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	6	469	$683,645	$2,330,869	$4,811,394
Florida	9	324	336,035	910,116	1,949,378
Georgia	6	305	297,346	92,935	477,074
Kentucky	17	963	837,449	787,233	3,105,483
North Carolina	11	814	676,088	923,960	2,055,263
Oklahoma	9	290	291,886	343,502	1,282,141
South Carolina	5	579	502,166	303,070	1,238,071
Tennessee	7	215	182,851	123,606	522,632
Texas	11	349	320,166	399,827	1,164,424
Virginia	12	441	427,151	376,198	1,242,663
Total	93	4,749	4,554,783	6,591,316	17,848,523

TABLE XXIV

Iron and Steel

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Blast Furnaces					
Alabama	12	4,157	$4,574,023	$35,558,188	$49,455,982
Tennessee	4	339	347,824	2,512,427	3,537,401
Total	16	4,496	4,921,847	38,070,615	52,993,383
Steel Works and Rolling Mills					
Alabama	9	7,473	11,010,770	47,777,718	73,487,368
Kentucky	5	4,542	6,639,791	24,538,758	35,987,067
Total	14	12,015	17,650,561	72,316,476	109,474,435
Cast-Iron Pipe					
Alabama	34	10,840	10,619,902	21,238,837	42,590,922
Tennessee	6	1,539	1,572,092	2,914,264	5,680,628
Total	40	12,379	12,191,994	24,153,101	48,271,550

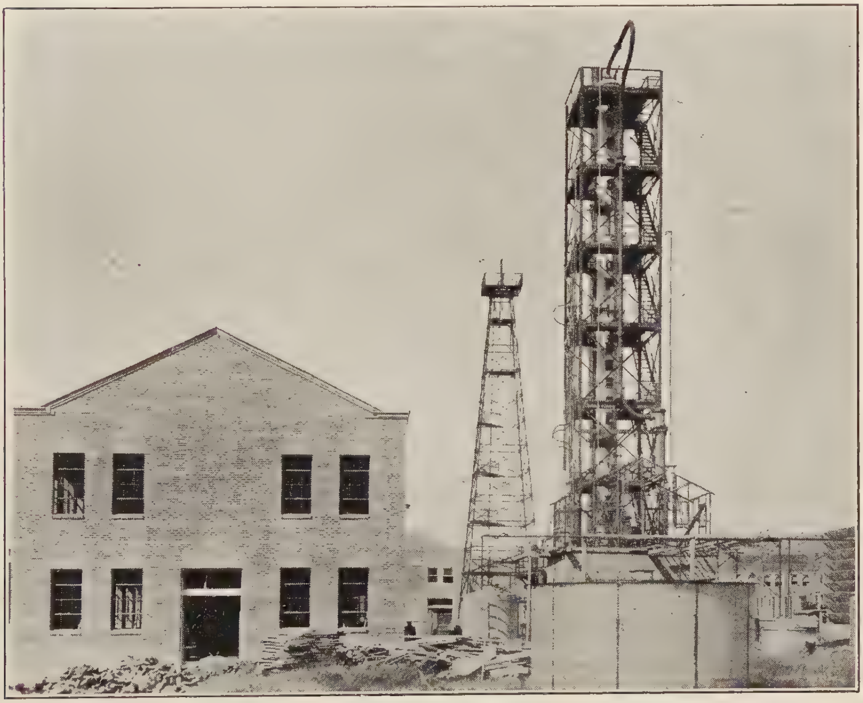

FIGURE 24.—PETROLEUM RESEARCH BUILDING AND EXPERIMENTAL REFINERY, UNIVERSITY OF OKLAHOMA, NORMAN, OKLAHOMA

TABLE XXV

Petroleum Refining

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Arkansas	8	350	$508,772	$10,313,177	$12,725,342
Kentucky	5	253	339,793	6,878,844	8,246,366
Louisiana	12	5,093	8,186,966	115,966,567	138,249,752
Oklahoma	46	5,207	7,749,884	131,031,534	153,278,576
Texas	62	13,726	19,683,149	364,640,509	429,501,524
Total	133	24,629	36,468,564	628,830,631	742,001,560

TABLE XXVI

Refining Capacity of Petroleum Industry in the South

(Compiled from *Oil and Gas Journal* by Blue Book of Southern Progress, 1930)

	No. of plants	*Daily crude capacities (barrels)*	*Plants operating*	*Capacity operating plants (barrels)*	*Plants with cracking production*	*Cracking capacities (barrels)*
Arkansas	11	49,500	9	48,000	6	16,750
Georgia	1	5,000	1	5,000	1	3,600
Kentucky	11	30,800	8	26,900	6	10,700
Louisiana	16	243,680	11	207,780	6	96,000
Oklahoma	64	357,800	44	313,900	29	117,050
South Carolina	1	15,000	1	15,000	1	18,523
Tennessee	3	1,250	...	.....	...	......
Texas	110	882,250	81	813,700	38	494,950
Virginia	1	1,500	1	1,500	...	......
Total	218	1,586,780	156	1,431,780	87	757,573
United States	479	3,972,460	362	3,721,360	186	1,705,299

TABLE XXVII

Paints and Varnishes

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alabama	6	48	$50,836	$646,232	$1,002,408
Florida	5	13	16,717	103,565	173,057
Georgia	10	115	78,665	485,510	972,527
Kentucky	22	429	530,455	5,403,041	9,975,983
Louisiana	9	87	107,766	1,036,290	1,713,054
Tennessee	13	163	154,343	1,147,064	2,065,376
Texas	11	101	121,336	1,416,817	2,301,613
Virginia	8	63	70,080	394,940	681,526
Total	84	1019	1,130,198	10,633,459	18,885,544

TABLE XXVIII

Medicinal Preparations

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Patent and Proprietary Medicines and Compounds					
Arkansas	8	16	$13,390	$65,611	$177,224
Florida	15	68	66,347	478,151	1,117,597
Georgia	25	201	128,519	1,077,169	3,967,290
Kentucky	12	54	45,725	185,173	658,312
Louisiana	18	106	72,260	481,129	1,350,310
North Carolina	12	97	79,744	574,728	2,002,161
South Carolina	3	8	2,703	10,372	31,835
Tennessee	24	413	388,503	1,858,454	6,596,615
Texas	21	85	98,541	584,916	1,564,573
Virginia	16	89	90,863	589,264	1,853,801
Total	154	1137	986,595	5,904,967	19,319,718
Druggists' Preparations					
Alabama	4	10	3,755	21,644	71,785
Tennessee	8	111	84,478	896,526	1,724,785
Texas	8	101	83,370	353,067	835,949
Total	20	222	171,603	1,271,237	2,632,519

TABLE XXIX

Miscellaneous Chemicals and Chemical Manufactures

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Alcohol, Ethyl					
Louisiana	8	270	$335,802	$3,977,825	$6,292,750
Bone Black, Carbon Black, and Lampblack					
Louisiana	34	800	923,558	3,172,006	7,182,698
Texas	13	299	491,640	1,333,260	3,312,228
Total	47	1,099	1,415,198	4,505,266	10,494,926
Chemicals, Not Elsewhere Classified					
Tennessee	6	771	1,000,292	4,637,410	9,846,545
Virginia	9	1,357	1,561,326	3,565,302	8,169,829
Total	15	2,128	2,561,618	8,202,712	18,016,374
Cleaning and Polishing Preparations					
Tennessee	4	14	9,855	50,108	121,368
Texas	6	16	14,236	52,606	149,748
Total	10	30	24,091	102,714	271,116

TABLE XXIX—(*Continued*)

	Number of establishments	*Wage earners (average for year)*	*Wages*	*Cost of materials, supplies, containers for products, fuel, and power*	*Value of products*
Coke, Not Including Gas-House Coke					
Alabama	8	1759	2,459,179	17,991,036	25,510,423
Tennessee	3	131	172,477	1,057,168	1,471,414
Virginia	7	265	220,089	1,057,288	1,420,783
Total	18	2155	2,851,745	20,105,492	28,402,620
Explosives					
Kentucky	4	33	36,187	149,929	274,836
Oklahoma	5	10	18,786	79,015	313,013
Total	9	43	54,973	228,944	587,849
Flavoring Extracts and Flavoring Sirups					
Georgia	8	134	148,606	3,734,194	7,868,299
Kentucky	3	15	9,780	22,534	46,698
Louisiana	8	59	56,425	1,727,652	4,099,980
Tennessee	6	36	22,581	242,546	485,903
Texas	11	53	78,433	1,490,060	3,688,976
Total	36	297	315,825	7,216,986	16,189,856
Perfumes, Cosmetics, and Other Toilet Preparations					
Georgia	9	61	33,829	201,539	535,160
Louisiana	4	35	19,182	106,865	208,170
Oklahoma	3	19	14,404	81,588	177,398
Tennessee	10	380	283,051	1,575,078	5,215,852
Texas	6	29	15,316	84,653	284,236
Virginia	4	25	22,737	94,336	289,164
Total	36	549	388,519	2,144,059	6,709,980
Salt					
Louisiana	4	843	452,220	1,733,312	3,705,883
Smelting and Refining, Zinc					
Oklahoma	6	1,717	2,502,541	12,727,781	15,207,105
Vinegar and Cider					
Texas	6	43	30,692	321,103	683,441
Virginia	4	216	160,812	540,723	874,964
Total	10	259	191,504	861,826	1,558,405

TABLE XXX

Principal Mineral Products of Thirteen Southern States

The data given in this table were compiled from a bulletin of the Department of Commerce, "Mineral Resources of the United States in 1928, Preliminary Summary."

TABLE XXX—(*Continued*)

The figures given apply to the calendar year 1927. The values for manganese ore and manganiferous ore given separately in the report were added. Items produced and collected not given separately are included in "Miscellaneous." Qualifying notes of no great importance as regard the total figures given are omitted.

	Asphalt	*Barite*	*Bauxite*	*Cement*	*Clay products*
Alabama	$128,700	$......	$24,690	$10,615,428	$4,823,670
Arkansas	......	......	1,892,860	......	1,285,720
Florida	......	......	......	......	462,190
Georgia	......	580,300	71,230	......	4,879,736
Kentucky	3,156,700	......	......	......	7,257,664
Louisiana	......	......	......	......	446,156
Mississippi	......	......	......	......	1,146,472
North Carolina	......	......	......	......	3,860,950
Oklahoma	......	......	......	......	1,693,669
South Carolina	......	......	......	......	1,802,772
Tennessee	......	129,990	......	6,580,732	3,728,380
Texas	1,254,500	......	......	10,232,908	6,417,017
Virginia	......	......	......	......	2,932,998

	Clay—Raw	*Coal*	*Coke*	*Copper*	*Gypsum*
Alabama	176,418	44,524,000	13,500,234	......	......
Arkansas	1,966	5,393,000	......	......	......
Florida	646,415	......	......	......	......
Georgia	1,537,378	233,000	......	......	......
Kentucky	662,149	119,249,000	......	......	......
Louisiana	......	......	......	......	......
Mississippi	20,308	......	......	......	......
North Carolina	327,688	191,000	......	713,048	......
Oklahoma	......	11,570,000	......	......	2,073,944
South Carolina	743,742	......	......	......	......
Tennessee	661,813	10,645,000	1,149,604	1,957,217	......
Texas	19,063	1,998,000	......	2,811	4,003,456
Virginia	211,869	23,203,000	1,413,595	......	......

	Iron ore	*Iron pig*	*Lead*	*Lime*	*Manganese ore Manganiferous ore*
Alabama	12,973,597	50,193,057	......	1,566,287	......
Arkansas	......	......	2,898	307,335	112,880
Florida	......	......	......	59,491	......
Georgia	147,068	......	......	99,604	136,094
Kentucky	......	......	17,514	47,620	......
Louisiana	......	......	......	......	......
Mississippi	......	......	......	......	......
North Carolina	81,753	......	......	......	......
Oklahoma	......	......	6,511,680	......	......
South Carolina	......	......	......	......	......
Tennessee	274,620	1,911,380	......	1,266,326	11,624
Texas	......	......	30,743	733,678	......
Virginia	172,877	1,782,538	301,518	1,317,581	84,222

TABLE XXX—(*Concluded*)

	Natural gas	*Natural gasoline*	*Petroleum*	*Phosphate rock*	*Salt*
Alabama	......	......	......	......	......
Arkansas	4,281,000	2,281,000	42,400,000	......	......
Florida	......	......	......	8,646,162	......
Georgia	......	......	......	......	......
Kentucky	3,277,000	547,000	11,220,000	......	......
Louisiana	12,158,000	2,442,000	29,740,000	......	2,167,220
Mississippi	......	......	......	......	......
North Carolina	......	......	......	......	......
Oklahoma	41,391,000	29,114,000	397,200,000	......	......
South Carolina	......	......	......	......	......
Tennessee	2,200	......	90,000	2,318,785	......
Texas	37,424,800	18,347,000	248,550,000	......	399,171
Virginia	......	......	......	......	......

	Sand and gravel	*Silver*	*Stone*	*Zinc*	*Miscellaneous*
Alabama	1,292,233	......	1,797,375	......	2,975,147
Arkansas	832,520	......	486,792	16,384	156,711
Florida	930,504	......	6,138,767	......	1,494,247
Georgia	295,505	......	6,146,613	......	4,140,544
Kentucky	1,718,055	......	2,863,779	110,080	8,407,996
Louisiana	1,910,064	......	169,643	......	2,333,838
Mississippi	1,372,089	......	......	......	35,072
North Carolina	871,416	......	4,913,177	......	6,243,641
Oklahoma	1,331,222	......	1,514,538	26,446,208	5,555,402
South Carolina	397,781	......	1,992,558	......	58,026
Tennessee	1,842,144	46,188	6,430,631	1,331,200	10,415,640
Texas	4,694,134	586,769	2,534,866	......	37,010,167
Virginia	1,217,450	......	3,320,385	1,065,600	8,533,120

To the mineral production listed the following should be added:

		Value
Chats	Oklahoma	$69,000
Feldspar	North Carolina	612,214
Fluorspar	Kentucky	1,040,338
Fuller's Earth	Texas	283,400
Graphite	Alabama	146,730
Marl, calcareous	Virginia	77,851
Mica, Scrap	North Carolina	50,505
Mica, Sheet	North Carolina	114,514
Silica (Quartz)	North Carolina	19,853
Slate	Virginia	398,612
Talc	Georgia	42,370
Tripoli	Oklahoma	124,069
Zircon	Florida	364,600

Texas in 1928 produced sulfur valued at $37,455,000 which was 99.88% of the total sulfur produced in the United States.

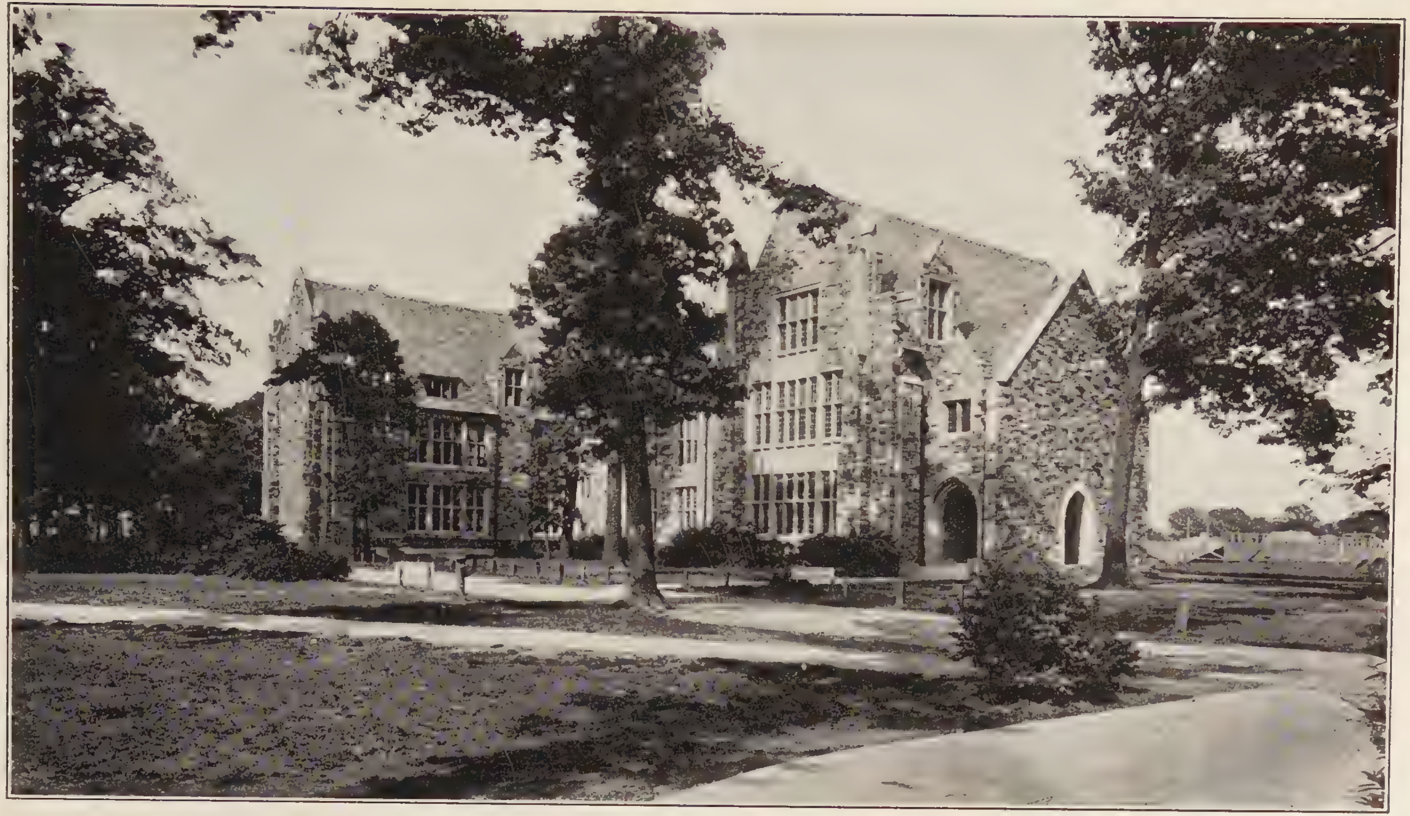

Figure 25.—Chemistry Building, Southwestern College, Memphis, Tennessee. Erected 1925
Planned throughout as a chemical laboratory. Now used in part for other sciences.

TABLE XXXI

New Industrial Developments in the South

(Selected notices taken from the Blue Book of Southern Progress for 1930)

A glance at the list given below will give some idea of the rapid expansion now taking place in chemical industry in the South. Note both the diversity of location and the diversity of industry.

Louisville, Ky. The American Cigar Company expended about $2,500,000 on plant improvements.

New Orleans, La. The Celotex Company greatly expanded its facilities.

Clewiston, Fla. The Southern Sugar Company expended $12,000,000 up to the end of 1929. Their present program calls for the expenditure of an additional $60,000,000 within the next seven years.

Kingsport, Tenn. The Tennessee Eastman Corporation began operation of part of a $2,000,000 plant for the manufacture of cellulose acetate.

Alcoa, Tenn. The Aluminum Company of America completed an aluminum bronze powder mill.

Alcoa, Tenn. The U. S. Aluminum Company started work on an aluminum rolling mill.

Aluminum company interests are undertaking extensive hydro-electric developments through the Tallassee Power Company and the Nantahala Power and Light Company.

Gadsden, Ala. The Gulf States Steel Company is pushing work on a $5,000,000 expansion program and has announced plans involving a total expenditure of $20,000,000.

Birmingham, Ala. The Tennessee Coal, Iron, and Railroad Company in 1929 doubled the capacity of its rolling and galvanizing departments at its Fairfield sheet mills, made extensive improvements to its Fairfield and Ensley works and announced plans for a further extension program, featuring a new sheet mill, modernization of the Ensley plant, and further extensions to the Fairfield plant.

Tampa, Fla. The United States Phosphoric Products Corporation started work on a $4,500,000 plant.

Henryetta, Okla. The Pittsburgh Plate Glass Company completed in 1930 a $2,000,000 plant.

Richmond, Va. The American Tobacco Company started work in 1929 on additions to its plant involving the expenditure of about $3,500,000.

Gadsen, Ala. The Goodyear Tire and Rubber Company completed a $7,500,000 unit of a tire plant and a $1,000,000 rubber reclaiming plant.

Silvertown, Ga. The B. F. Goodrich Rubber Company completed an $8,500,000 plant for the production of tire fabric and acquired a site in Atlanta for a tire plant.

Savannah, Ga. The Southern Building Products Corporation is building a $600,000 asphalt roofing and shingle plant in connection with the erection of a $1,000,000 asphalt refinery for the Pan-American Petroleum and Transport Company.

The Georgia Manganese and Iron Company of Atlanta expended about $2,000,000 in developing manganese properties.

Pensacola, Fla. The Newport Company and Armstrong Cork and Insulation Company are erecting a $1,000,000 insulating board plant.

Greenville, Miss. The Greenville Insulating Board Corporation erected a $1,000,000 plant.

Ducktown, Tenn. The Ducktown Chemical and Iron Company reported a $1,000,000 acid plant expansion.

Nashville, Tenn. The du Pont Cellophane Company, Inc., constructed a transparent wrapping paper plant.

Memphis, Tenn. Procter and Gamble Company let contracts for a $1,000,000 chemical cotton plant.

Graham, N. C. The Esther Dye Works completed its plant.

Burlington, N. C. The Ideal Mercerizing Company was organized.

Spartanburg, S. C. The Fairforest Finishing Company completed a $1,000,000 plant.

Greenville, S. C. The Union Bleachery made additions and improvements amounting to $350,000.

Rock Hill, S. C. The Rock Hill Printing and Finishing Company completed a $2,000,000 plant.

Hartsville, S. C. The Hartsville Print and Dye Works completed a $1,000,000 plant.

Covington, Va. The Industrial Rayon Corporation completed a plant for the manufacture of fine denier and multi-filament yarns by the viscose process, to have an annual capacity of approximately 6,000,000 pounds.

Waynesboro, Va. The du Pont Rayon Company completed a plant for the production of acetate rayon, the initial unit to have a capacity of 1,500,000 to 2,000,000 pounds annually.

Ampthill, near Richmond, Va. The du Pont Company completed a viscose process rayon plant with an initial capacity of 3,500,000 pounds annually. It is estimated that this plant and the plant at Waynesboro involved the expenditure of $16,000,000.

Hopewell, Va. The Tubize Artificial Silk Corporation of America greatly increased the output of its plant, which now has a capacity close to 10,000,000 pounds.

Roanoke, Va. The Viscose Company of Virginia continued to expand its huge plant, already the country's largest, with an output estimated at 20,000,000 pounds annually.

Rome, Ga. The American Chatillon Corporation completed a plant to produce 19,000 pounds of rayon yarn daily, the output to be made up of two distinct rayon products: a fine thread manufactured from cotton linters by a cellulose acetate process and thread of a coarser texture made by the viscose process.

Asheville, N. C. The American Enka Corporation completed a rayon plant at an estimated cost of $10,000,000 with a capacity of 5,000,000 pounds of viscose yarn.

Burlington, N. C. The A. M. Johnson Rayon Mills, Inc., put into operation initial units of a rayon plant, the development of which has been carried forward with little or no publicity as to process or output. Another unit is scheduled for completion in 1930.

Bemberg, Tenn. The American Glanzstoff Corporation went forward with erection of the second big unit of its rayon plant, with the intention of doubling the capacity of the existing plant and to involve an expenditure of perhaps $7,000,000.

Old Hickory, near Nashville, Tenn. The du Pont Rayon Company undertook extensive improvements and additions to its plant.

Louisville, Ky. The Brown Wood Preserving Company started construction of a large modern creosoting plant.

Columbus, Miss. The T. J. Moss Tie Company completed a wood-treating plant with a yearly capacity of 700,000 treated ties.

Mobile, Ala. The International Paper Company completed a $5,000,000 plant alongside of which a $1,500,000 steam and electric power plant was built to supply the power for the paper mill. This company has four other paper mills in the South.

Lynchburg, Va. The John H. Heald Company completed a $2,000,000 liner board plant.

West Point, Va. The Albemarle-Chesapeake Company, Inc., started work in 1929 on a 100-ton paper mill to cost about $1,500,000 and expanded the mill of the Chesapeake Corporation at a cost of about $300,000.

Fredericksburg, Va. The Sylvania Industrial Corporation has completed a $1,000,000 transparent paper plant.

Richmond, Va. The Standard Paper Manufacturing Company expended about $500,000 for improvements.

Canton, N. C. The Champion Fibre Company continued its expansion program.

Memphis, Tenn. The Buckeye Cotton Oil Company pushed work on a paper-pulp plant.

Monroe, La. The Brown Paper Mill Company started work on additions costing $5,000,000 to double the capacity of its plant.

Tuscaloosa, Ala. The Gulf States Paper Company completed a paper mill and bag plant estimated to have involved an expenditure of over $6,000,000.

Waco, Texas. The Atlas Portland Cement Company of Texas completed a $3,000,000 plant.

Longhorn, Texas. The Republic Portland Cement Company completed a cement plant.

Okay, Ark. The Arkansas Portland Cement Company completed a cement plant.

Vicksburg, Miss. The National Portland Cement Company of Mississippi made plans for a $1,000,000 plant.

Texarkana, Ark.-Tex. The International Agricultural Corporation completed a $750,000 fertilizer plant.

Tampa, Fla. The American Cyanamid Company began work on a $4,000,000 superphosphate development.

Sidney, Fla. The American Cyanamid Company expended $300,000 for the purpose of opening a new phosphate deposit.

Jackson, Miss. The F. S. Royster Guano Company purchased a site on which it is proposed to erect a $250,000 plant.

Tampa, Fla. The Tennessee Copper and Chemical Company completed a superphosphate plant.

Nacogdoches, Tex. The Texas Fertilizer Company completed a superphosphate plant.

Roxboro, Va. The Davison Chemical Company completed a fertilizer factory.

Petersburg, Va. The Davison Chemical Company completed a fertilizer factory.

Houston, Tex. The Davison-Pick Fertilizers, Inc., started work on a $700,000 plant.

Bartow, Fla. The Southern Phosphate Company started work on a $500,000 development.

Tuscaloosa, Ala. The Southern Cities Supply Corporation completed $200,000 improvements to its shale brick plant.

Needham, Ala. The Choctaw Clay Corporation was organized to construct a $500,000 brick and clay plant.

Malvern, Ark. The Acme Brick Corporation was understood to have expended $250,000 in increasing the capacity of its plant.

Newspaper Item

Panama City, Fla. The Southern Kraft Corporation has announced plans for a $10,000,000 paper mill to be constructed at once.

CHEMICAL PROGRESS IN THE SOUTH

PART V. CHEMICAL PERIODICALS AND REFERENCE BOOKS IN THE LIBRARIES OF THE SOUTH

PART V

CHEMICAL PERIODICALS AND REFERENCE BOOKS IN THE LIBRARIES OF THE SOUTH

Foreword

J. E. Mills, National Research Council, Washington, D. C.

The real value of a library to an institution and to a community does not depend on the value of the periodicals and books which it contains but on the use which is made of them. It is with the desire to increase the usefulness of the technical library facilities in the South that Part V of this volume has been prepared.

In the lists given sets are regarded as complete when only a part of one volume is missing. In general this missing part could and should be supplied by obtaining a photostat copy of the missing papers.

Build up the library with a view to supplying adequately the needs of the institution and the community and build for the future. The writer firmly believes that by the coöperation of the public and institutional libraries mentioned in this book it will be quite possible for many communities in the South in a period of five years to build up technical reference libraries of which the community might well be proud.

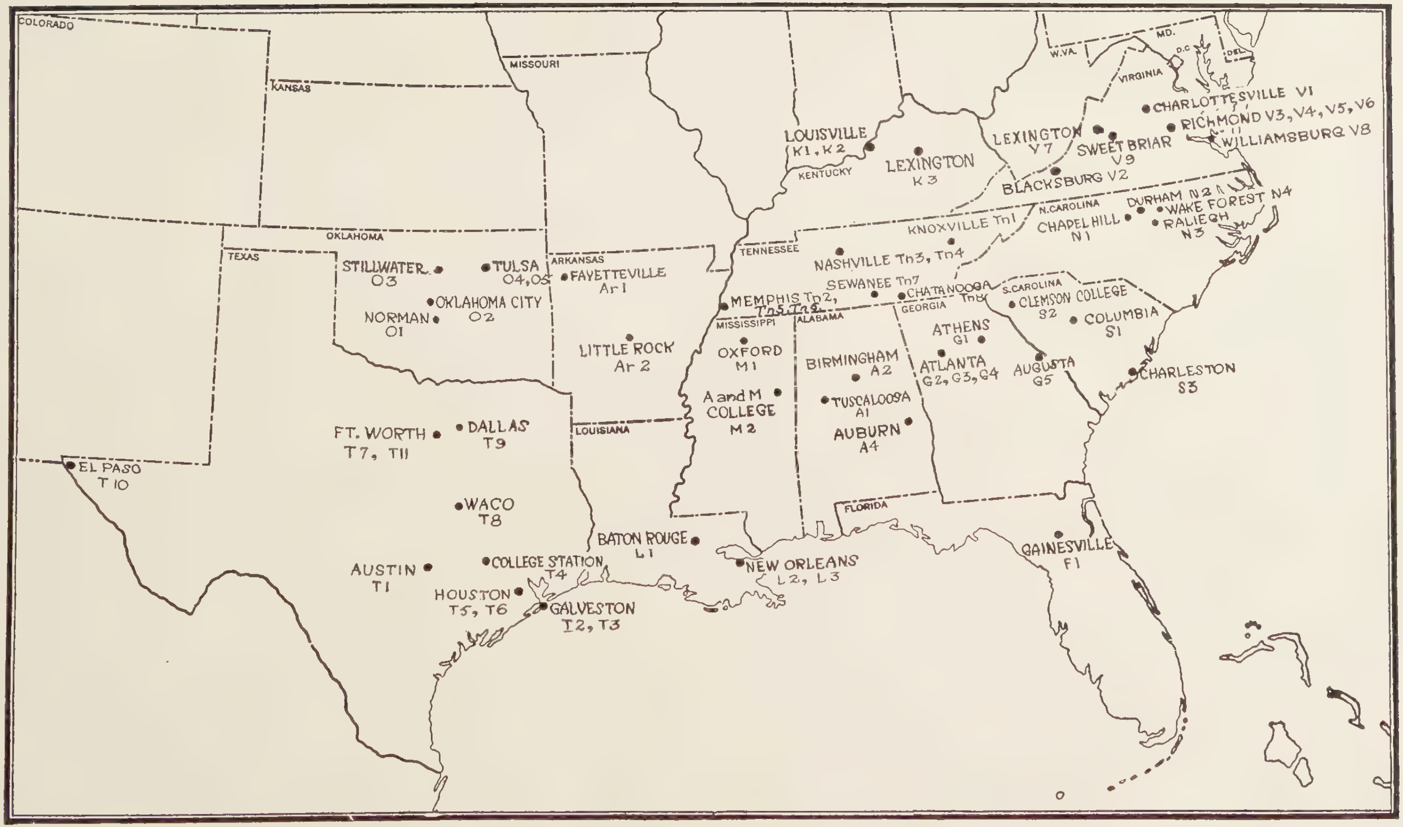
COLORADO
KANSAS
MISSOURI
OKLAHOMA
TEXAS
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
TENNESSEE
KENTUCKY
GEORGIA
FLORIDA
S.CAROLINA
N.CAROLINA
VIRGINIA
W.VA.
MD.
D.C
DEL.
STILLWATER O3
TULSA O4, O5
OKLAHOMA CITY O2
NORMAN O1
FAYETTEVILLE Ar 1
LITTLE ROCK Ar 2
FT. WORTH T7, T11
DALLAS T9
EL PASO T 10
WACO T8
AUSTIN T1
COLLEGE STATION T4
HOUSTON T5, T6
GALVESTON T2, T3
BATON ROUGE L1
NEW ORLEANS L2, L3
MEMPHIS Tn2, Tn5, Tn6
OXFORD M1
A and M COLLEGE M2
BIRMINGHAM A2
TUSCALOOSA A1
AUBURN A4
LOUISVILLE K1, K2
LEXINGTON K3
NASHVILLE Tn3, Tn4
KNOXVILLE Tn1
SEWANEE Tn7
CHATANOOGA Tn8
ATHENS G1
ATLANTA G2, G3, G4
AUGUSTA G5
CLEMSON COLLEGE S2
COLUMBIA S1
CHARLESTON S3
GAINESVILLE F1
LEXINGTON V7
SWEET BRIAR V9
BLACKSBURG V2
CHARLOTTESVILLE V1
RICHMOND V3, V4, V5, V6
WILLIAMSBURG V8
CHAPEL HILL N1
DURHAM N2
WAKE FOREST N4
RALIEGH N3

FIGURE 26.—LOCATION OF CHEMICAL LIBRARIES IN THE SOUTH

CHAPTER XXXVI

CHECK LIST OF CHEMICAL PERIODICALS IN LIBRARIES OF THE SOUTH

Clarence J. West and Callie Hull, National Research Council, Washington, D. C.

The data contained in this chapter have been compiled from information supplied by sixty libraries located in the South.

Since the primary purpose of this study is to present a survey of chemical education and industry in the southern states, the library information covers only those periodicals abstracted by *Chemical Abstracts*. Each library was asked to check the 1500 or more journals currently covered by *Chemical Abstracts*, as represented by the list published in 1926 and a supplementary list containing new journals established since that date. The information given below, therefore, does not give a complete picture of the facilities of the coöperating libraries, nor does it represent simply those periodicals which might be termed "chemical."

In so far as possible, the year in which a periodical was established and the current volume number are given immediately following the name. Then follow the data reported by the libraries. The expression "1+" indicates that the library has a complete file of the periodical; "2–4," only volumes 2–4; "16+," a file beginning with volume 16. "Current" may indicate that the periodical is currently received but is not bound, or that the library reporting simply checked the entry without giving any indication of the completeness of the file.

No attempt was made by most of the libraries to report the actual numbers of government and state publications which they have. The list on pages 2496–7 is simply an indication of places where more or less complete sets are available.

Statistical data concerning the libraries will be found in Chapter II.

The coöperating libraries, with the designations used, follow (see also map showing location of these libraries opposite this page).

Institutions and Code Numbers by States

Virginia

V 1	University of Virginia, University.
V 2	Virginia Polytechnic Institute, Blacksburg.
V 3	Medical College of Virginia, Richmond.
V 4	University of Richmond, Richmond.
V 5	Richmond Public Library, Richmond.

V 6 Virginia State Library, Richmond.
V 7 Washington and Lee, Lexington.
V 8 William and Mary College, Williamsburg.
V 9 Sweet Briar College, Sweet Briar.

North Carolina

N 1 University of North Carolina, Chapel Hill.
N 2 Duke University, Durham.
N 3 North Carolina State College, Raleigh.
N 4 Wake Forest College, Wake Forest.

South Carolina

S 1 University of South Carolina, Columbia.
S 2 Clemson Agricultural College, Clemson.
S 3 Medical College of the State of South Carolina, Charleston.

Georgia

G 1 University of Georgia, Athens.
G 2 Georgia School of Technology, Atlanta.
G 3 Emory University, Emory University.
G 4 Carnegie Library of Atlanta, Atlanta.
G 5 University of Georgia, Medical School, Augusta.

Florida

F 1 University of Florida, Gainesville.

Alabama

A 1 University of Alabama, University.
A 2 Birmingham Public Library, Birmingham.
A 4 Alabama Polytechnic Institute, Auburn.

Mississippi

M 1 University of Mississippi, University.
M 2 Mississippi Agricultural and Mechanical College, Agricultural College.

Louisiana

L 1 Louisiana State University, Baton Rouge.
L 2 Tulane University, New Orleans.
L 3 Howard Memorial Library, New Orleans.

Texas

T 1 University of Texas, Austin.
T 2 University of Texas School of Medicine, Galveston.
T 3 Rosenberg Library, Galveston.

T 4 Agricultural and Mechanical College of Texas, College Station.
T 5 Rice Institute, Houston.
T 6 Houston Public Library, Houston.
T 7 Texas Christian University, Fort Worth.
T 8 Baylor University, Waco.
T 9 Baylor University, College of Medicine, Dallas.
T 10 El Paso Public Library, El Paso.
T 11 Carnegie Public Library, Fort Worth.

Oklahoma

O 1 University of Oklahoma, Norman.
O 2 University of Oklahoma, Medical School, Oklahoma City.
O 3 Oklahoma Agricultural and Mechanical College, Stillwater.
O 4 Tulsa Public Library, Tulsa.
O 5 University of Tulsa, Tulsa.

Arkansas

Ar 1 University of Arkansas, Fayetteville.
Ar 2 University of Arkansas, Medical School, Little Rock.

Kentucky

K 1 University of Louisville, Louisville.
K 2 Louisville Free Public Library, Louisville.
K 3 University of Kentucky, Lexington.

Tennessee

Tn 1 University of Tennessee, Knoxville.
Tn 2 University of Tennessee, School of Medicine, Nashville.
Tn 3 Vanderbilt University, Nashville.
Tn 4 Carnegie Library, Nashville.
Tn 5 Goodwyn Institute, Memphis.
Tn 6 Cossett Library, Memphis.
Tn 7 University of the South, Sewanee.
Tn 8 Chattanooga Public Library, Chattanooga.

Check List of Periodicals

Abhandlungen der mathematisch-physischen Klasse der sächsischen Akademie der Wissenschaften zu Leipzig. 1849.
Tn 3, **1–8, 10–29.**

Abstracts of Bacteriology. **1–9.** 1917–1925.
V 2, **1–9;** V 3, **1–9;** V 8, **5–8;** N 3, **1–9;** T 1, **1–9;** T 4, **1–9;** T 5, **3–9;** O 2, **1–6;** K 3, **1–9;** Tn 1, **1–3, 5–9;** Tn 2, **1–9;** Tn 3, **1–9.**

Acetylene Journal. 1899. **31.**
T 5, **26**+.

Acta Chirurgica Scandinavica. Continues *Nordiskt medicinskt Arkiv.*, **52** (1919). **66.**
N 2, **1**+; Tn 3, **52**+.

Acta Medica Scandinavica. Continues *Nordiskt medicinskt Arkiv.*, **52** (1919). **73.**
N 2, **1**+; Tn 3, **52**+.

Acta Medicinalia in Keijo. **13.**
Tn 2, **11**+.

Acta Pathologica et Microbiologica Scandinavica. 1924. **7.**
N 2, **1**+; T 2, **2–4.**

Acta Scholae Medicinalis Universitatis Imperialis in Kioto. 1916. **12.**
V 1, current; T 2, **1**+; Tn 3, **1, 3**+.

Acta Societatis Scientiarum Fennicae. 1842.
T 1, **21–24, 26–27, 31–32.**

Agricultural Gazette of Canada. **1–11.** 1914–1924.
V 1, **1–11;** F 1, **1–11;** K 3, **1–7;** Tn 1, **1–11.**

Agricultural Gazette of New South Wales. 1890. **41.**
V 2, **1**+; S 2, **31**+; F 1, **1**+; O 3, **25**+; K 3, **21**+; Tn 1, **16**+.

Agricultural Journal of India. 1906. **25.**
V 2, **1–20;** F 1, **1**+; O 3, **20**+; K 3, **12**+.

Agricultural Research Institute, Pusa: Bulletins. 1906.
V 2, **4–163** (inc.); S 2, **1929**+; F 1, **1**+; O 3, current; K 3, **1**+; Tn 1, 1907+.

Aichi Journal of Experimental Medicine. **1,** nos. 1–4. 1923–1924.
V 3, **1.**

American Chemical Journal. **1–50.** 1879–1913.
V 1, **1–50;** V 4, **1–50;** V 6; V 7, **4–31;** N 1, **1–50;** N 2; N 3, **1891–1913;** N 4, **1–50;** S 1; G 3; A 1, **1–50;** M 2, **1–50;** L 1; L 2; T 1; T 2, **1–5, 8–50;** T 4; T 5; T 8, **21–50;** O 1, **31–37, 39, 48;** O 2; O 3; Ar 1, **1–50;** K 1; Tn 1; Tn 3; Tn 4.

American City. 1909. **42.**
V 1, current; V 2, **12–33, 40**+; V 5, **31–41;** V 8, **25**+; N 2, **2, 4–21, 23–38;** N 3, **26**+; G 4, **2**+; A 4, **2**+; L 1, **1**+; L 2, **27**+; T 1, **1**+; T 3, **1**+; T 4, **1915**+; T 6, **1**+; T 7, **14–40;** T 10, **12**+; T 11, current; O 1, **9**+; O 3, current; Ar 1, current; K 2, **1–18, 20**+; K 3, **21–31, 33**+; Tn 1, **2–5, 7–14, 16**+; Tn 4, **1**+; Tn 5, **1**+; Tn 6, **1–40;** Tn 8, current.

American Druggist and Pharmaceutical Record. 1871. **81.**
V 3, **62**+; F 1, **1**+; M 1, current; T 1, **13–78** (inc.); O 1, **77**+; K 3, **63**+; Tn 2, **70–78;** Tn 3, **26–43, 47–61.**

American Dyestuff Reporter. 1916. **19.**
S 2, **10**+.

American Fertilizer. 1894. **72.**
V 2, **38**+; N 3, **10**+; S 1, **1923–1929;** S 2, **1–6, 32**+; F 1, **1916–1925;** A 1, **1925–1929;** M 2, **1**+; T 4, **44–70;** O 3, **32–48, 64**+; K 3, current; Tn 1, **33–45** (inc.), **56**+.

American Food Journal. 1906.
N 2, **20, 22;** N 3, **20**+; M 2, current; T 1, **19, 21;** O 3, **22**+; Ar 1, **1**+; K 3, **1**+; Tn 1, **17**+.

American Gas Association Monthly. 1919. **12.**
V 2, **11**+; A 1, **1**+; A 2, **11**+; T 6, **9**+.

American Gas Journal. 1859. **132.**
G 4, **114**+; A 2, **106**+; O 4, **128**+; Tn 1, **122**+.

American Journal of Anatomy. 1901. **45.**
V 1, **1**+; V 3, **19**+; V 9, **28–31;** N 1, **1**+; N 2, **1**+; S 3, **1**+; G 1, **32–39;** G 3, current; A 2, **39**+; M 1, current; L 2, **25**+; T 1, **1**+; T 2, **1**+; T 4, **13**+;

T 5, 33+; T 9, current; O 1, 1, 12–13, 28, 30+; O 2, 1+; O 3, 41+; Ar 1, 1+; Ar 2, 1+; K 3, 7–8, 13, 15, 18–44; Tn 2, 1+; Tn 3, 1+.

American Journal of Botany. 1914. 17.
V 1, 1+; V 2, 1+; V 8, 13+; N 1, 1+; N 2, 14+; N 3, 1+; S 2, 10+; G 1, 1+; G 3, 14+; F 1, 1+; A 4, 3, 5–6, 8+; M 2, 1+; L 1, 1+; T 1, 1+; T 4, current; T 8, 1–16; O 1, 1–6, 8+; O 3, 1, 16+; Ar 1, 1+; K 3, 3+; Tn 1, 1–6, 8+.

American Journal of Diseases of Children. 1911. 39.
V 1, 13+; V 3, 1+; N 2, 1+; S 3, 1+; G 3, current; A 2, 7–22, 24–28, 30+; L 1, 38+; T 1, 1+; T 2, 1+; T 9, current; O 2, 1+; O 3, 32+; Ar 1, current; Ar 2, 1919+; K 1, 1+; K 3, 28+; Tn 2, 1–8 (inc.), 9+; Tn 3, 1+.

American Journal of Hygiene. 1921. 11.
V 3, 1+; N 2, 1+; S 3, 1+; G 1, 1+; G 3, current; M 1, current; T 1, 1+; T 2, 1+; T 5, 1+; T 9, current; O 1, 8+; O 2, 4–9; Ar 1, current; Ar 2, 1+; K 3, 7–8.

American Journal of Pathology. Continues *Journal of Medical Research.* 1925. 6.
V 1, 1+; V 3, 1+; N 1, 1+; N 2, 1+; N 3, 1+; S 3, 1+; G 3, current; F 1, 3+; A 1, current; A 2, 1+; A 4, 5+; T 2, 1+; T 9, current; O 2, 1+; Ar 2, 1+; K 1, 1+; K 3, 1+; Tn 2, 1+; Tn 3, 1+.

American Journal of Pharmacy. 1829. 102.
V 3, 87+; N 1, 1+; S 3, 46–54; G 3, current; A 2, 6–11; A 4, 26+; M 1, current; T 1, 25, 52, 100+; T 2, 23–82 (inc.), 83+; O 1, 1+; K 3, 14+; Tn 2, 96+; Tn 3, 42–94.

American Journal of Physiology. 1898. 91.
V 1, 1+; V 3, 31+; N 1, 62+; N 2, 2+; N 3, 79+; S 3, 34+; G 1, 11+; G 3, current; A 2, 30, 36+; M 1, current; L 1, 75+; T 1, 1+; T 2, 1+; T 4, 45–55, 61+; T 5, 47+; T 8, 28+; T 9, current; O 1, 86+; O 2, 1+; O 3, 10–12, 81+; Ar 2, 1+; K 1, 6+; K 3, 23+; Tn 1, 6+; Tn 2, 1–5 (inc.), 6–34, 36+.

American Journal of Psychiatry. 1921. 9.
V 1, current; N 2, 1+; O 2, 1+; K 1, 1+.

American Journal of Public Health. 1911. 20.
V 3, 1+; V 8, 11+; N 1, 10+; N 2, 1+; N 3, 1+; S 3, 2+; G 3, current; F 1, 10–11, 13+; A 2, 13+; M 1, current; L 1, 1+; T 1, 5+; T 2, 1+; T 4, 7–20; T 5, 7+; T 6, 8+; T 8, 12–19; T 9, current; T 11, 7+; O 1, 4+; O 2, 2+; O 3, 19+; Ar 1, 9+; K 1, 3+; K 3, 3+; Tn 1, 11+; Tn 2, 1+; Tn 3, 2, 4+; Tn 6, 20+.

American Journal of Roentgenology and Radium Therapy. 1906; [n. s.] 1913. 23.
V 1, 23+; V 3, 9+; N 2, 1+; S 3, 2+; G 3, current; A 2, 4–11, 13+; T 2, 7+; T 9, current; O 2, 1+; Ar 1, 1+; Ar 2, 1+; K 1, 8+; Tn 2, 3+; Tn 3, 7+.

American Journal of Science. 1818. [5] 19.
V 1, [2] 13–14, 16–18, 20–46, 49–50; [3] 1–2, 5–50; [4] 1–33, 37+; N 1, 1+; N 2, [4] 11–50; [5] 1–17; N 3, [5] 7+; A 1, 1+; A 2, 15+; M 1, 26–32 (inc.), 33+; L 1, 1–90, 92–101, 129–130, 191–192, 194–196, 199–202; L 2 [2] 1+; L 3, [4] 1+; T 1, 1+; T 4, [4] 13+; T 5, 1+; T 6, 11+; T 7, [4] 47+; T 8, 9+; T 10, [3] 7; [4] 6, 14; O 1, [1]–[5] 2; O 3, 12+; O 4, 1+; O 5, 16–19; Ar 1, 1+; K 2, 43–44, 47–63, 91–92, 101–108, 117–154, 159–215, 217+; K 3, [4] 1–4, 6–10, 17+; Tn 1 [1] 21; [3] 15–18, 31–34, 36–48; [4] 5–10, 13–15; [5] 1+; Tn 3, 1+; Tn 5, [4] 25–36; [5] 12+.

American Journal of Syphilis. 1917. 14.
V 1, 1+; V 3, 1+; N 2, 1+; S 3, 1+; G 3, current; A 2, 1–2, 4+; T 2, 1+; O 2, 1+; Ar 2, 1+; K 1, 1+; K 3, 5+; Tn 2, 1+; Tn 3, 1+.

American Journal of the Medical Sciences. 1827. [n. s.] 1841. **179.**
V 1, 1+; V 3, 1+; N 2, 1+; S 3, 6–26; [n. s.] 1–39, 41+; A 1, current; A 2, [n. s.] 16, 32, 36, 38–54; M 1, current; T 2, 1+; T 9, current; O 1, 161–172, 174+; O 2, 1+; Ar 2, 1852+; K 1, current; K 2, 119–000, 1907–1922; K 3, 11–13, 26, 74–81, 131–138, 140–152, 154–156, 163–166, 173+; Tn 2, 1–25 (inc.); [n. s.] 3+ (inc.); Tn 3, 1–26; [n. s.] 2+ (inc.).

American Journal of Tropical Medicine. 1921. **10.**
V 1, 1–4; V 3, 1+; N 2, 1+; S 3, 1+; A 4, 1–4; M 2, 1+; L 1, 1+; T 2, 1+; T 5, 1+; T 9, current; O 2, 1+; Ar 2, 1–4; K 1, 1+; Tn 2, 1+; Tn 3, 1+.

American Medicine. 1901. **36.**
V 3, 1+; S 3, 8–9; A 2, 1–5, 7, 9–16, 18–21; T 2, 1+; K 2, 1906–1916; K 3, 11, 20–21; Tn 2, 1–11, 14; Tn 3, 1–16, 19–32.

American Miller. 1873. **58.**
O 3, 56+; K 3, current.

American Mineralogist. 1916. **15.**
V 1, 5+; N 1, 1+; A 1, 1+; L 1, 1+; T 1, 1+; T 4, 6+; Ar 1, 1+; O 1, 1–7, 11+; Tn 3, 1+.

American Naturalist. 1867. **64.**
V 1, 1+; V 2, 1–9, 11–18, 20–39, 43–60; V 6, 1–6, 8, 42+; V 8, 1+ (inc.); N 1, 1+; N 2, 1+; N 3, 57+; S 2, 36+; G 1, 38+; G 3, 1–15, 62+; F 1, 1+; A 4, 21–47; M 2, 1+; L 1, 4–7, 13–15, 24–27, 43, 45+; L 2, 28–29, 32, 34, 37+; L 3, 26+; T 1, 1+; T 4, 34+; T 5, 1+; T 8, 56–61; T 11, 45+; O 1, 1+; O 3, 1–4, 25–26, 31–38, 52+; O 5, 60+; Ar 1, 1+; K 2, 1+; K 3, 1+; Tn 1, 1–6, 14–28, 30; Tn 2, 61+; Tn 3, 30–31, 33–49 (inc.), 50+; Tn 6, 1–15, 29–32, 35–55, 57–62.

American Perfumer and Essential Oil Review. 1906. **24.**
V 3, 9+; V 4, 23+; F 1, 24+; O 1, 21+.

American Railway Engineering Association, Bulletin. 1900.
V 2, 23+; L 2, 25+; T 4, 1–20; T 5, 19+.

American Review of Tuberculosis. 1917. **21.**
V 1, 1+; V 3, 1+; N 2, 1+; S 3, 6+; M 1, current; T 1, 4+; T 2, 1+; O 2, 1+; K 1, 7+; K 3, 19+; Tn 2, 1+.

American Veterinary Review. 1–47. 1877–1915. Continued as *Journal of the American Veterinary Medical Association.*

Anales de la asociacion quimica Argentina. 1913. **17.**
N 1, 1+.

Anales de la sociedad cientifica Argentina. 1876.
A 1, current.

Anales de la sociedad española de fisica y quimica. 1903. **28.**
N 2, 25–26.

Analyst, The. 1876. **55.**
V 2, 9+; N 1, 4–51; N 2, 1+; N 3, 20–41; S 2 18+; A 1, current; M 2, 1+; A 4, 13+; T 1, 1+; T 4, 16–29; T 5, 1+; O 1, 46+; O 3, 1–42; K 3, 3+.

Anatomical Record. 1906. **45.**
V 1, 1+; V 3, 10+; V 9, 1919–1923; N 2, 1+; S 3, 1+; M 1, current; L 2, 15+; T 2, 1+; T 4, 7+; T 5, 7+; T 7, 1+; T 9, current; T 7, 1+; T 9, current; O 1, 1+; O 2, 1+; O 3, 45+; Ar 2, 1+; K 3, 2, 5, 10–12, 16–17, 22–23, 41+; Tn 1, 1+; Tn 2, 1+; Tn 3, 1+.

Anatomischer Anzeiger. 1886. **69.**
V 1, 30+; N 2, 1+; T 1, 1+; O 2, 1+.

Annalen der Chemie, Justus Liebig's. 1832. **478.**

V 1, **1+**; V 7, **1+**; N 1, **1+**; N 2, **1+**; N 3, **237–308**; G 1, **158–445, 453+**; F 1, **1–411, 421–441, 443–451**; M 2, **1+**; L 2, **1+**; T 1, **1+**; T 5, **1+**; O 1, **1–413, 415+**; Ar 1, **1+**; K 2, **169–174**; K 3, **1+**; Tn 1, **1+**; Tn 2, **477+**; Tn 3, **1–416, 421+**.

Annalen der Physik. 1799. [5] **4.**

V 1, **1+**; N 1, **1+**; N 2, **1824+**; G 1, **1924+**; F 1, [n. s.] **30–38**; [4] **16–87**; [5] **1+**; T 1, [2] **121–160**; [3] **1–69**; [4] **1–87**; [5] **1+**; T 5, **1+**; O 1, [n. s.] **54–69**; [4] **1+**; K 3, **1+**; Tn 1, **58+**; Tn 3, **1–160**; [2] **1–37, 39–69**; [3] **1–50, 52–54, 59+**.

Annales de chimie. 1914. [3] **13.**

V 1, **1+**; V 7, **1+**; N 1, **1+**; N 2, **1+**; G 1, **1+**; M 1, **1+**; T 1, **1+**; T 5, **1+**; Ar 1, **1+**; Tn 3, **13–20**; Tn 3, **1+**.

Annales de chimie analytique et de chimie appliquée et revue de chimie analytique réunies. 1896.

Tn 3, **1+**.

Annales de chimie et de physique. 1789–1913.

K 2, **1–255, 257–260, 262–270.**

Annales d'hygiène publique, industrielle et sociale. 1923. **8.**

N 2, **1+**.

Annales de l'institut de platine. **1930.**

V 7, **1+**.

Annales de l'institut Pasteur. 1887. **44.**

V 1, **14+**; V 3, **26+**; S 3, **12–20**; M 2, **27–37, 39, 42+**; T 2, **1–2, 6+**; T 5, **14+**; T 9, current; O 2, **28, 30–31, 33–39, 41+**; K 1, **40+**; K 3, **42+**; Tn 3, **1+**.

Annales de la science agronomique française et ètrangére. 1884. **46.**

O 3, **1884–1890, 1920+**.

Annales de médecine. 1914. **27.**

V 1, **7+**; V 3, **1+**; N 2, **1+**; O 2, **7–24**; Tn 2, **4–16** (inc.), **17+**; Tn 3, **7–14, 20, 25+**.

Annales de physique. 1914. [3] **13.**

V 1, **1+**; V 7, **1+**; N 1, **1+**; N 2, **1+**; G 1, **1+**; T 1, **1+**; T 4, **10–20**; T 5, **1+**; O 1, **1+**.

Annales des sciences naturelles—Zoölogie. 1834. [10] **12.**

N 2, [10] **7+**.

Annales et bulletin de la société royale des sciences médicales et naturelles de Bruxelles. 1840.

T 5, **55+**.

Annals of Applied Biology. 1914. **17.**

V 2, **1+**; M 2, **1+**; O 3, **3, 15+**; Ar 1, current; K 3, **7+**.

Annals of Botany. 1887. **44.**

V 1, **1–36, 40+**; V 2, **30+**; V 9, current; N 1, **1+**; N 2, **1+**; N 3, **25–26, 38–42**; S 2, **42+**; G 1, **21+**; G 3, **41+**; F 1, **1+**; A 4, **33, 35+**; M 2, **29–37, 39+**; L 1, **1+**; L 2, **28+**; Ar 1, **1+**; T 1, **1+**; T 4, **1+**; O 1, **1–37, 39+**; O 3, **43+**; K 3, **2–6, 29–30, 32+**; Tn 1, **1+**.

Annals of Clinical Medicine. **1–5.** 1922–1927. Continued as *Annals of Internal Medicine.*

V 3, **1–5**; N 2, **1–5**; S 3, **2–5**; T 2, **1–5**; O 2, **1–5**; K 1, **1–5**; Tn 2, **1–5**.

Annals of the Entomological Society of America. 1908. **23.**

S 2, **1+**; F 1, **10–12, 14, 17, 20+**; A 4, **1+**; L 1, current; T 5, **1+**; O 3, **1+**; Ar 1, current.

Annals of the Missouri Botanical Gardens. 1914.
V 2, 1+; V 8, 1+; V 9, 1–9, 11, 13; N 1, 1+; N 3, 1+; S 2, 1+; G 1, 1+; F 1, 1+; A 4, 1+; M 2, 1+; L 1, 14+; T 1, 1+; O 1, 1, 12+; O 3, 1+; K 3, 1+; Tn 1, 1+.

Annals of Surgery. 1885. 91.
V 1, 33+; V 3, 17+; N 2, 1+; S 3, 1+; A 2, 5–37, 40–54, 56+; O 2, 1–45, 47–50, 57–66, 70–74, 76–87; Ar 2, 1889–1895, 1900+; K 1, 1+; K 2, 3–8; K 3, 43–58, 60–61, 63–72, 89+; Tn 2, 1–15, 17+; Tn 3, 1+.

Annals of Tropical Medicine and Parasitology. 1907. 24.
S 3, 13+; A 2, 8–10; L 1, 1+; T 2, 1–4, 11+; T 4, 20–22; T 5, 22+; O 2, 15–22; Tn 3, 1+.

Arbeiten aus dem Reichsgesundheitsamte. 61.
N 2, 1+.

Arbeiten aus dem Staatsinstitut für experimentelle Therapie und dem Georg Speyer-Hause zu Frankfort, A. M. 1905. No. 22 (1929).
N 2, 1+.

Archief voor de Suikerindustrie in Nederlandsch-Indie. 1893. 48.
L 1, 1+.

Archiv der Pharmazie und Berichte der deutschen pharmazeutischen Gesellschaft. 1822. 268.
N 1, 205–258; N 2, 1+; A 4, 201–241, 243–250, 266+; T 1, 2–5, 7–13, 15–69; O 1, 67–238, 265+.

Archiv für Dermatologie und Syphilis. 1869. 159.
V 1, 2+; N 2, 1+; A 2, 15+; T 2, 21–22, 25–29, 31–33, 110, 117, 154+.

Archiv für die gesamte Physiologie des Menschen und der Tiere (*Pflüger's*). 1868. 223.
V 1, 119+; N 1, 116+; N 2, 1+; T 1, 1+; T 2, 1+; T 5, 54+; O 2, 156–159, 193–221.

Archiv für Entwicklungsmechanik der Organismen, Wilhelm Roux' (*Abteilung D of Zeitschrift für wissenschaftliche Biologie*). 1865. 121.
N 2, 1+; T 2, 110+; Tn 1, 28–41, 45+; Tn 2, 109–120; K 3, 35–41.

Archiv für experimentelle Pathologie und Pharmakologie. 1873. 148.
V 3, 96+; N 1, 1+; N 2, 1+; F 1, 148+; T 2, 1+; O 2, 74–78, 80, 103–140; Tn 2, 120+; Tn 3, 1+.

Archiv für Gynaekologie. 1870. 140.
V 1, 90+; N 2, 1+; Tn 3, 1+.

Archiv für Hygiene. 1883. 103.
V 1, 12+; V 2, 57–59, 61–62; N 2, 1+; Tn 3, 1–32.

Archiv für Kinderheilkunde. 1880. 89.
V 1, 8–46; N 2, 1+; Tn 3, 1+.

Archiv für mikroskopische Anatomie und Entwicklungsmechanik. 1865.
N 2, 1+; O 2, 1+; Tn 1, 98+; Tn 2, 86–104; Tn 3, 1+.

Archiv für pathologische Anatomie und Physiologie und für klinische Medizin. (*Virchow's.*) 1847. 275.
N 1, 19+; N 2, 1+; T 2, 1+; O 2, 236+; Tn 3, 1+.

Archiv für Protistenkunde. 1902. 69.
V 1, 165+; N 2, 1+; G 3, 1+; L 2, 10–36; T 1, 1–40, 42+; T 2, 1–31; T 5, 1+; Ar 1, 1+; Tn 3, 1–58.

Archiv für Schiffs- und Tropen-Hygiene, Pathologie und Therapie exotischer Krankheiten. 1897. 34.
N 2, 1+; T 2, 28–29, 33+; T 5, 1+; Tn 2, 1–26.

Archiv für Verdauungskrankheiten mit Einschluss der Stoffwechselpathologie und der Diätetik. 1895. **47.**
N 2, **1+**; T 2, **13–30**; Tn 3, **1–20, 22+**.

Archiv für Zellforschung. **1–17.** 1908–1923.
N 2, **1–17**; Tn 3, **1–12.**

Archives de biologie. 1880. **39** (1929).
V 1, **29–33**; N 1, **1+**; N 2, **1+**; T 1, **1+**; T 9, current; O 1, **1+**; Tn 3, **1–5, 15–16, 22–25, 27–28, 36+**.

Archives institut Pasteur d'Algerie. 1923. **8.**
V 1, current; T 2, **2+**.

Archives institut Pasteur de Tunis. 1906. **19.**
V 1, current; T 2, **12+**.

Archives internationales de médicine expérimentale. 1924. **5.**
Tn 3, **1+**.

Archives internationales de pharmacodynamie et de therapie. 1894. **36.**
O 2, **1** +.

Archives internationales de physiologie. 1904.
V 1, **9+**; T 2, **3, 21, 26+**; K 3, **21+**; Tn 3, **1+**.

Archives italiennes de biologie. 1882. **82.**
N 2, **1+**; T 2, **73+**.

Archives néerlandaises de physiologie de l'homme et des animaux. 1916. **15.**
N 1, **1+**: N 2, **1+**; T 2, **1+**; T 5, **1+**; Tn 3, **1+**.

Archives néerlandaises des sciences exactes et naturelles. **1866.** [n. s.] 1897–1911.
N 1, **1+**; T 1, [1] **28+**; T 5, **1+**; Tn 1, [1] **1–30**; [2] **1–12.**

Archives of Dermatology and Syphilology. 1920. **21.**
V 1, **2+**; N 2, **1+**; S 3, **1+**; T 2, **1+**; T 9, current; O 2, **1+**; Ar 2, **1+**; K 1, current; K 3, **2, 4, 6–15, 17, 19+**; Tn 2, **1+**.

Archives of Diseases in Childhood. 1926. **5.**
N 2, **1+**; S 3, **1+**; Ar 2, **1+**.

Archives of Internal Medicine. 1908. **45.**
V 3, **1+**; N 1, **1+**; N 2, **1+**; S 3, **1+**; A 2, **13–34, 36+**; T 1, **1+**; T 2, **1+**; T 9, current; O 2, **1+**; Ar 1, current; K 1, **1+**; K 3, **23+**; Tn 2, **1+**; Tn 3, **1+**.

Archives of Neurology and Psychiatry. 1899. **23.**
V 1, **1+**; V 3, **1+**; N 2, **1+**; S 3, **12+**; T 2, **1+**; T 9, current; O 1, **21+**; O 2, **2–11**; Ar 2, **1+**; K 1, **1+**; Tn 2, **1+**; Tn 3, **2+**.

Archives of Pathology. 1926. **9.**
V 1, **1+**; V 3, **1+**; N 2, **1+**; S 3, **1+**; T 1, **9+**; T 2, **1+**; T 9, current; Ar 1, current; Ar 2, **1+**; K 1, **1+**; K 3, **9+**; Tn 2, **1+**.

Archives of Pediatrics. 1884. **47.**
V 1, **29+**; V 3, **23+**; N 2, **1+**; S 3, **18–25, 28+**; A 2, **32+**; T 1, **1+**; T 2, **1+**; T 9, current; O 2, **1+**; Ar 1, current; Ar 2, **1+**; K 1, **1+**; Tn 2, **1+**; Tn 3, **1+**.

Archives of Physical Therapy, X-Ray and Radium. 1920. **11.**
V 1, **3–8, 10+**; V 3, **7+**; N 2, **1+**; S 3, **1+**; T 9, current; O 2, **7–10**; K 1, current; Tn 2, **7+**.

Archives of Surgery. 1920. **20.**
V 1, **20+**; V 3, **1+**; N 2, **1+**; S 3, **1–5, 7+**; A 2, **1–7, 10+**; T 2, **1+**; T 9, current; O 2, **1+**; Ar 2, **1+**; K 1, **1+**; K 3, **18+**; Tn 2, **1+**; Tn 3, **1+**.

Archivio di fisiologia. 1903. **28.**
N 2, **1+**.

Archivio per le scienze mediche. 1876. **54.**

N 2, 1+.

Arkiv för Kemi, Mineralogi och Geologi. 1903. **10.**

N 1, 1–8.

Arkiv för Matematik, Astronomi och Fysik. 1903. **22.**

T 5, 1+.

Aromatics. 1920.

Tn 2, 10+.

Astrophysical Journal. 1895. **71.**

V 8, 54+; N 1, 12, 17+; N 2, 1+; N 3, 61–68; G 1, 1+; G 2, 66+; G 3, 51+; F 1, 63+; A 1, 1+; L 1, 1+; L 2, 1+; T 1, 1+; T 4, 46+; T 5, 1+; O 1, 1+; O 3, 59+; K 3, 41+; Tn 1, 1+; Tn 3, 69+.

Atlantic Medical Journal. 1897. **33.** 1–26 (1897–1923) as *Pennsylvania Medical Journal.*

T 2, 3+; O 2, 28–31; T 9, current.

Atti della reale accademia nazionale dei Lincei (*Rendiconti classe di scienze fisiche, matematiche e naturali*). 1876.

T 5, 1+.

Australian Journal of Experimental Biology and Medical Science. 1924. **7.**

V 1, 1+; L 1, 4+; K 3, 1–5.

Beiträge zur Klinik der Tuberkulose und spezifischen Tuberkulose-Forschung. 1903. **74.**

V 1, 74+.

Beiträge zur pathologische Anatomie und zur allgemeiner Pathologie. 1886. **84.**

N 2, 1+; T 2, 1–22, 70; K 1, 61+; Tn 3, 1+.

Beiträge zur Physiologie. 1914. **4.**

N 2, 1+; Tn 3, 1–3.

Bell Laboratories Record. 1925.

V 1, current; V 2, 2+; T 5, current; O 1, 1+; K 2, 1929+.

Bell System Technical Journal. 1922. **9.**

V 1, 1–2, 7+; V 2, 1+; N 2, 3, 8; N 3, 4+; S 2, 5+; G 1, 4+; G 2, 1+; G 3, 7+; G 4, 8+; F 1, 1+; A 2, 8+; M 1, current; M 2, 1+; L 1, 6+; T 1, 1+; T 4, 1+; T 5, 1+; T 10, 7+; O 1, 1+; O 4, 6+; Ar 1, 1+; K 2, 1+; K 3, 1+; Tn 1, 1+; Tn 4, current; Tn 6, 3–7.

Berichte der deutschen botanischen Gesellschaft. 1882. **48.**

V 1, 47+; V 2, 24+; N 1, 1+; N 2, 1+; G 1, 25+; F 1, 1–36; A 4, 39+; T 1, 1–37, 39+; T 4, 38–40; O 1, 1+.

Berichte der deutschen chemischen Gesellschaft. 1868. **63.**

V 1, 1+; V 2, 1+; V 3, 61+; V 7, 9+; N 1, 1+; N 2, 1+; N 3, 17–44, 57–60; S 1, 1+; S 2, 18–22; G 1, 15+; G 2, 18, 31–35, 48; G 3, 1+; F 1, 1+; A 1, current; A 4, 7–24, 53+; M 1, 1+; M 2, 1+; L 1, 1+; L 2, 1+; T 1, 1+; T 2, 1+; T 5, 1+; O 1, 1+; O 3, 11–55, 57+; Ar 1, 8+; K 3, 1–56; Tn 1, 1+; Tn 3, 1–42, 44–49, 51+; Tn 7, 1+.

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N 2, 1903–1919.

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T 1, **11+**.

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N 3, **18–28**; M 2, **33+**; K 3, **11–13**; Tn 1, **36+**.

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V 1, **1–4**; N 3, **1–3.**

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V 1, **19+**; V 3, **7+**; N 1, **17+**; N 2, **1+**; N 3, **22+**; S 3, **23+**; G 1, **24+**; G 3, current; G 5, **1+**; F 1, **1–16** (inc.), **17+**; A 2, **20+**; A 4, **1+**; L 1, **23+**; T 1, **6+**; T 2, **1+**; T 5, **1+**; T 9, current; O 1, **1+**; O 2, **1–7, 17–22**; O 3, **1–22**; Ar 1, current; Ar 2, **1+**; K 1, **18+**; K 3, **10+**; Tn 1, **22+**; Tn 2, **1+**; Tn 3, **1+**.

Biochemische Zeitschrift. 1906. **217.**
V 1, **167+**; N 1, **101–176**; N 2, **1+**; S 3, **207+**; G 5, **1+**; L 1, **203–208, 210+**; T 1, **1+**; T 2, **1+**; T 5, **1+**; O 1, **1–105**; O 2, **105–206**; O 3, **1–104**; Tn 2, **1+**; Tn 3, **1+**.

Biologia generalis. 1925. **6.**
T 5, current.

Biological Abstracts. 1927. **4.**
V 1, **1+**; V 2, **1+**; V 3, **1+**; N 2, **1+**; N 3, **1+**; S 2, **1+**; S 3, **2+**; G 1, **1+**; G 2, **1+**; G 3, **1+**; F 1, **1+**; A 4, **3+**; M 1, current; M 2, **1+**; L 1, **1+**; T 1, **1+**; T 2, **1+**; T 4, **1+**; T 7, **1+**; T 8, **1+**; T 9, current; O 1, **1+**; O 2, **1+**; O 3, **1+**; Ar 1, **1+**; Tn 1, **1+**; Tn 2, **1+**; Tn 3, **1+**.

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T 1, **1+**.

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N 1, **1+**; N 2, **1+**; T 1, **12–19.**

Biometrica. 1901. **22.**
V 2, **1–20**; N 2, **1+**; F 1, **17+**; T 1, **1+**; K 3, current; Tn 1, **20+**.

Blast Furnace and Steel Plant. 1912. **18.**
A 1, **1+**; A 2, **9+**.

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V 1, **66–84, 151+**; V 3, **153+**; N 2, **1+**; A 2, **51–197** (inc.); T 2, **3–197** (inc.); O 2, **37, 69–70, 178–202**; K 1, current; K 3, **154–171, 173, 197+**; Tn 2, **44–163** (inc.), **164–197**; Tn 3, **22–142** (inc.), **145–197.**

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V 1, **1–15**; V 2, **1–15**; V 3, **1–15**; N 1, **1–15**; N 2, **1–15**; N 3, **1–6, 11, 13–15**; S 2, **1–15**; G 1, **1–15**; G 3, **1–15**; F 1, **1–15**; M 2, **1–15**; L 1, **1–15**; L 2, **1–15**; T 1, **1–15**; T 4, **11–15**; T 5, **1–15**; T 8, **1–8, 12–15**; O 1, **1–15**; O 3, **1–4, 5–6** (inc.), **15**; Ar 1, **1–15**; K 3, **1–15**; Tn 1, **1–15**; Tn 3, **1–15.**

Botanical Gazette. 1875. **89.**
V 1, **1+**; V 2, **11+**; V 8, **71+**; V 9, **77–85, 87+**; N 1, **1+**; N 2, **32–86**; N 3; **1–12, 14–43, 45+**; S 2, **1+**; G 1, **20+**; G 3, **65+**; F 1, **1+**; A 4, **8, 10+**; M 2, **19, 21–25, 27–34, 36+**; L 1, **1+** (inc.); L 2, **1+**; T 1, **12+**; T 4, **25+** (inc.),

T 7, **81+**; T 8, **12–85**; T 11, **50+**; O 1, **1–8, 15+**; O 3, **16–43, 46, 61, 63+**; Ar 1, **1+**; K 3, **1+**; Tn 1, **1+**; Tn 3, **29–87** (inc.); **88+**.

Botanisches Centralblatt. 1880. **16 (158).**

V 1, **1–132**; V 2, **107+**; N 2, **1+**; N 3, **41–44, 89–102, 104–122**; F 1, **47+**; A 4, **143+**; L 1, **92–126, 128–130**; T 1, **71+**; O 1, **108, 110–114, 116–130, 148+**.

Brain. 1878. **53.**

V 1, **1+**; V 3, **40+**; N 1, **45–51**; N 2, **1+**; S 3, **42+**; A 2, **37–38, 40–41**; T 2, **1+**; T 5, **15+**; T 9, current; O 2, **39, 48–52**; Ar 2, **1879–1884, 1887+**; K 1, current; K 2, **2–9** (inc.); Tn 2, **1+**; Tn 3, **1+** (inc.).

Brass World and Platers' Guide. 1905. **26.**

A 2, **20+**; Tn 1, **25+**.

Brennstoff-Chemie. 1920. **11.**

N 1, **1+**; A 1, **1+**; T 1, **1+**.

Brick and Clay Record. 1892. **76.**

N 3, **66+**; S 2, **68+**; G 2, **66+**; A 1, **1+**; A 2, **60+**; L 1, **70+**; T 1, **60+**; O 3, **72+**.

British Chemical Abstracts. 1926. **1930** (No vol. no.).

V 2, **1926+**; V 7, **1926+**; N 2, **1926+**; G 3, **1930+**; A 4, **1926+**; M 1, current; M 2, **1+**; L 1, current; L 2, **1926+**; T 1, **1926+**; T 2, **1926+**; T 4, **1926+**; O 1, **1926+**; O 3, **1927+**; K 1, **1926+**; K 3, **1926+**; Tn 1, **1926+**; Tn 3, **1926+**.

British Food Journal. 1899.

K 3, **1–20.**

British Journal of Experimental Biology. Continued as *Journal of Experimental Biology.*

British Journal of Experimental Pathology. 1920. **11.**

V 3, **6+**; N 1, **1–8**; N 2, **1+**; S 3, **1+**; F 1, **9+**; T 2, **1+**; T 5, **1+**; T 9, current; O 2, **6–9**; Ar 2, **1+**; K 3, **1+**; Tn 3, **1+**.

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N 2, **1–32**; O 2, **29–30.**

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O 2, **1–23.**

British Journal of Tuberculosis. 1907. **24.**

N 2, **1+**; T 2, **1, 3, 11+**; O 2, **19–23.**

British Journal of Urology. 1929. **2.**

K 1, **1+**.

British Medical Journal. 1857. **1930-I.**

V 1, **1+**; V 3, **1875+**; N 1, **1923+**; N 2, **1+**; S 3, **1880–1912, 1916+**, A 2, **1878–1879, 1882–1886, 1905–1908, 1914+**, T 2, **1857+**; T 9, current; O 2, **1914+**; Ar 2, **1+**; K 1, **1895+**; K 3, **1906–1913, 1915–1917, 1927+**; Tn 2, **1878–1909** (inc.), **1910+**; Tn 3, **1863–1865, 1871–1872, 1874–1875, 1878+**.

Brooklyn Botanic Garden Record. 1912.

V 2, **4+**; S 2, **13–15.**

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N 1, **1921+**.

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L 1, **44+**.

Bulletin de la classes des sciences, academie royale de Belgique. 1899.

T 1, **58, 60, 68, 70, 72–75, 77, 79–89.**

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N 2, **6–7.**

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N 1, **1918+**.

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N 2, **1+**; T 9, current; Tn 2, **9–11** (inc.), **18–19**; Tn 3, **1+**.

Bulletin de la société botanique de France. 1854. **76** (1929).
T 1, **1+**.

Bulletin de la société de chimie biologique. 1914. **12.**
O 2, **1+**; Tn 3, **1+**.

Bulletin de la société chimique de France. 1858. [4] **47.**
V 7, **28+**; N 1, **1858–1928**; N 2, **1+**; G 1, **1+**; L 1, current; L 2, **1897–1925**; T 1, **1+**; T 5, **1+**; Ar 1, **1+**; K 3, [4] **13–14, 25–26, 33**; Tn 3, **33–36**; [4] **1+**.

Bulletin de la société géologique de France. 1830.
T 7, [3] **11–28**; [4] **1–22**; Tn 3, current.

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N 2, **1+**; T 2, **39–44**; Tn 2, [3] **53+**.

Bulletins et mémoires de la société nationale de chirurgie. 1875. **56.**
V 1, **21+**; Tn 3, **1+**.

Bulletin of Agricultural Intelligence and Plant Diseases. 1910.
F 1, **1–13**; O 3, **1912–1922.**

Bulletin of Entomological Research. 1910. **21.**
V 2, **16+**; N 2, **1+**; F 1, **19+**; T 5, **1+**; Tn 3, **1+**.

Bulletin of Hygiene. 1926. **5.** Supersedes *Tropical Diseases Bulletin. Sanitation Supplements.*
T 2, **1–3.**

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V 3, **22+**; N 1, **13, 17, 20–26, 30, 34–35**; F 1, **40+**; T 1, **3, 11+**; T 4, **33–37**; O 1, **35+**; Tn 2, **26–30, 31–32** (inc.), **38–42**; Tn 3, **12–32.**

Bulletin of the American Association of Petroleum Geologists. 1917. **14.**
V 1, **14+**; A 1, **1+**; L 1, **1+**; T 1, **1+**; T 4, **10+**; T 6, **1+**; T 7, **1+**; T 10, **1+**; O 1, **1+**; O 4, **1+**; O 5, **12+**; Tn 3, **1+**.

Bulletin of the American Ceramic Society. 1922. **9.** Published with the *Journal.*

Bulletin of the Antivenin Institute of America. 1927. **3.**
T 2, **1–2**; K 3, **1+**.

Bulletin of the Ayer Clinical Laboratory of the Pennsylvania Hospital. 1903.
T 2, **1+**; Tn 3, **1–3, 5+**.

Bulletin of the Buffalo General Hospital. 1923. **8.**
V 1, **1+**; T 2, **1+**; Tn 2, **1+**.

Bulletin of the Chemical Society of Japan. 1926. **5.**
N 1, **1+**; T 1, **1+**; K 3, **1+**.

Bulletin of the Geological Institution of the University of Upsala. 1892.
N 1, **1–19.**

Bulletin of the Geological Society of America. 1888.
V 1, **38+**; V 2, **1–25**; N 1, **1+**; A 1, current; A 2, **41+**; L1, **1+**; T 1, **1+**; T 6, **37+**; T 7, **25+**; T 10, **2–16, 20, 22+**; O 1, **1–27, 29+**; O 4, **27+**; Ar 1, current; K 3, **2, 8–27, 29+**; Tn 1, **2+**; Tn 3, **1+**.

Bulletin of the Geological Survey of Western Australia.
Tn 3, current.

Bulletin of the Imperial Institute. 1903. **28.**
S 2, **25+**; F 1, **1+**.

Bulletin of the Institute of Physical and Chemical Research, Tokyo; Abstracts. 1928. *Scientific Papers,* 1922. **9.**

G 1, **1+** (Abstracts); **4+** (Papers).

Bulletin of the Institution of Mining and Metallurgy. 1904.

Tn 3, current.

Bulletin of The Johns Hopkins Hospital. 1890. **46.**

N 1, **2+**; S 3, **2+**; T 1, **21+**; T 2, **1+**; O 2, **21–31, 33, 35–36, 38–49**; Ar 2, **5+**; K 1, **1912+**; K 3, **17–28, 44+**; Tn 2, **1+**.

Bulletin of the National Association of Wool Manufacturers. 1865.

V 3, **17+**; O 3, **58+**; Tn 1, **44+**.

Bulletin of the National Research Council. 1919. No. **75.**

V 1, **1–33, 35, 89, 91**; V 2, **49, 59+**; V 3, **1+**; N 1, **1–57**; G 1, **1+**; L 2, **48+**; T 5, **1–9, 11+**; Ar 1, **1+**; K 3 (inc. set); Tn 1, **1+**; Tn 3, **1+**.

Bulletin of the Torrey Botanical Club. 1870. **57.**

V 1, **1–51, 54+**; V 2, **14+** (inc.); N 1, **1+**; N 3, **22, 30+**; S 2, **27–30, 51+**; G 1, **36+**; F 1, **1+**; A 4, **46, 48+**; L 1, **1–33, 57+**; L 2, **36+**; L 3, **27–31**; T 1, **1+**; T 4, **26+** (inc.); O 1, **1+**; O 3, **1–33**; Ar 1, **1+**; K 3, **1+**; Tn 1, **1–13, 15–31, 33+**.

Bulletin of the United States National Museum.

V 2, **51+** (inc.); N 3, **57+** (inc.); S 2, **1886+**; L 1, **1+** (inc.); T 1, **1+**; T 10 (inc.); T 11 (inc.); O 1 (inc.); O 3 (inc.); O 5 (inc.); Ar 1, **1+**; K 2 (inc.); K 3 (inc.); Tn 1 (inc.); Tn 3 (inc.); T 4, **47+**; Tn 6, **1+**.

Bulletin of the Wagner Free Institute of Science.

T 1, **5+**; T 5, current; O 3, current; K 3, **4+**.

Bureau of Standards Journal of Research. 1928. **4.**

V 1, **1+**; V 2, **1+**; V 8, **1+**; N 1, **1+**; N 3, **1+**; S 2, **1+**; G 2, **1+**; G 4, **1+**; A 2, **1+**; A 4, **1+**; L 1, **1+**; L 3, **1+**; T 1, **4+**; T 3, **1+**; T 4, **1+**; T 5, **1+**; T 11, **1+**; O 3, **1+**; O 4, **4+**; K 3, **1+**; Tn 4, **1+**; Tn 5, **1+**; Tn 6, **1+**; Tn 8, current.

Butter and Cheese Journal. 1910. **21.**

V 2, **20+**; K 3, **5+**.

Camera, The. 1897. **40.**

V 2, **32+**.

Canadian Chemistry and Metallurgy. 1917. **14.**

V 7, **1+**; N 1, **2–13**; N 2, **12**; S 2, **3+**; A 1, **1+**; A 2, **7–8, 12+**; M 2, **7+**; T 1, **2+**.

Canada Department of Mines, Geological Survey, Publications.

A 1 (inc.); L 1 (inc.); T 1 (inc.); K 3 (inc.); Tn 3, **1+**.

Canadian Engineer, The. 1893. **58.**

S 2, **54+**; A 2, **54+**; T 1, **38–39, 47+**; T 4, **44+**; O 3, **58+**; Ar 1, current.

Canadian Journal of Research. 1929. **2.**

V 1, **1+**; V 2, **1+**; V 3, **1+**; V 8, **1+**; S 2, **1+**; F 1, **1+**; A 4, **1+**; L 1, **1+**; T 1, **2+**; T 5, **1+**; K 3, **1+**.

Canadian Medical Association Journal. 1911. **22.**

V 1, **22+**; V 3, **11+**; N 2, **1+**; A 1, current; A 2, **18+**; T 9, current; O 2, **14–20**; K 1, current; K 3, current; Tn 2, **6+**; Tn 3, **1+**.

Canadian Mining Journal. 1882. **51.**

A 1, **1+**; A 2, **49+**; O 1, **46+**; O 4, **51+**.

Canning Age. 1920. **11.**

S 2, **11+**; O 3, **8+**.

Carnegie Institution of Washington, Publications. 1902.

V 3, current; V 8, 1+; N 1, 1–400; G 1, 1+; A 1, 1+; L 1, 1+ (inc.); T 1, 2+ (inc.); Ar 1, 1+; K 2, 1+ (inc.); Tn 1, 1+; Tn 3, 1+.

Cellulose. 1930. **1.**

V 5, 1+.

Centralblatt für allgemeine Pathologie und pathologische Anatomie. 1890. **48.**

V 1, 46, 49–51, 55–59, 66–67; N 1, 1+; N 2, 1+; Tn 2, 30+; Tn 3, 1+.

Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten. I Abteilung (a) Referate. (b) Originale. II Abteilung. 1902. **I 115; II 80.**

V 1, 21–28, 42–44, 52–75; V 3, (a) 51+; (b) 62+; N 2, 1+; N 3, 1–44, 73+; G 1, 110+; A 4, 52+; L 1, current; T 1, 1+; T 2, 1+; T 5, 1+; O 2, (a) 40–42, 72–74, 88–115; (b) 60–61, 75+; Ar 1, current; K 3, (a) 49+, (b) 59+, II Abt. 30+; Tn 1, 1+; Tn 2, (a) 97+; Tn 3, 1+.

Centralblatt für die Zuckerindustrie.

A 1, current.

Centralblatt für Mineralogie, Geologie und Paläontologie. 1900. **1930.**

T 1, 1900+; O 1, 1926+; O 3, 1927+.

Ceramic Abstracts. 1922. **9.** Appears with *Journal of the American Ceramic Society.*

Ceramic Age. 1921. **15.**

N 3, 9+; G 2, 9+; A 1, current; A 4, current; L 1, 11–12, 14+; K 3, current.

Ceramic Industry. 1923. **14.**

N 3, 3+; A 1, 1+; Tn 8, current.

Chemical Abstracts. 1907. **24.**

V 1, 1+; V 2, 1+; V 3, 1+; V 4, 1+; V 6, 14+; V 7, 1+; V 8, 16+; V 9, 1+; N 2, 1+; N 4, 1+; S 2, 1+; G 1, 1+; G 4, 9+; F 1, 1+; A 2, 1+; A 4, 1+; L 1, 1+; L 2, 1+; L 3, 5–13; T 1, 1+; T 2, 1+; T 4, 1+; T 6, 20+; T 10, current; T 11, current; O 3, 1+; O 4, 12+; Ar 1, 1+; Tn 1, 1+; Tn 4, current; Tn 5, current; Tn 6, current; Tn 8, current.

Chemical Age (London). 1919. **22.**

N 3, 12–13; F 1, 1–5; A 2, 16–18.

Chemical Age (New York). **1–33.** 1904–1925.

V 8, 29–32; N 2, 15–33; S 1, 1–31; G 1, 28–33; A 1, 1–33; A 2, 29–32; L 2, 1921–1923; T 1, 1, 8, 10, 14, 16, 22–23, 25–33.

Chemical and Metallurgical Engineering. 1902. **37.**

V 1, 1+; V 2, 22+; V 3, 24+; V 4, 23–35; V 5, 31+; V 7, 1+; N 1, 1–35; N 2, 3+; N 3, 14–15, 18–21; S 1, 1+; S 2, 8+; G 1, 2–30; G 2, 1+ ; G 4, 15+; F 1, 24, 26, 28–30, 32+; A 1, 3+; A 2, 12+; A 4, 22+; M 2, 1+; L 1, 23–30, 32–35; L 2, 1+; T 1, 3+; T 4, 10+; T 5, 1+; T 6, 24+; T 7, 24+; T 10, 18+; T 11, 8+; O 1, 8+; O 3, 13+; O 4, 30+; Ar 1, 19+; K 1, 20+; K 2, 1910+; K 3, 7–11, 14–22, 24, 26+; Tn 1, 1+; Tn 3, 19+; Tn 5, 30+; Tn 8, current.

Chemical Engineer. 1904–1920.

N 2, 15–28; N 3, 11–26; A 1, 1+; L 2, 1905–1920; K 3, 1–8.

Chemical Engineering and Mining Review.

A 1, 1+.

Chemical Markets. 1914. **26.**

V 1, current; N 1, 1+; S 2, 20–23; A 2, 1928+.

Chemical News. 1859. **140.**

V 1, 25+; V 7, 31–33, 74–125; N 1, 2–137; S 2, 98–107; G 1, 91+; G 2, 1–6, 85+; G 3, current; A 1, 1+ (inc.); A 4, 1–64, 69+; M 1, 1+; M 2, 75+; L 2, 1885–1925; T 1, 1+; T 4, 117–127; T 5, 1+; K 2, 1–16, 21–24, 57–83, 97–127; K 3, 1+; Tn 1, 43–100 (inc)., 101+.

Chemical Reviews. 1924. **7.**
V 1, **1+**; V 2, **1+**; V 3, **1+**; V 4, **1+**; V 7, **1+**; V 9, **1+**; N 1, **1+**; N 2, **1+**; N 4, **1+**; S 1, **1+**; S 2, **1+**; G 1, **1+**; G 2, **1+**; G 3, **4+**; F 1, **1+**; A 1, current; A 2, **1+**; A 4, **1+**; M 1, current; M 2, **1+**; L 1, **4+**; L 2, **1+**; T 1, **1+**; T 2, **1+**; T 5, **1+**; T 7, **4+**; T 8, **1–4**; Ar 1, **1+**; K 3, **1+**; Tn 3, **1+**.

Chemicals. **33.**
V 2, **26+**; V 8, **27+**; N 1, **1–32**; N 2, **25+**; N 3, **25–29**; S 2, **30+**; G 1, **25+**; A 1, **1+**; A 2, **25+**; M 2, current; L1, current; L 2, **23+**; T 1, **1925+**; T 3. **27–32**; T 5, **1+**; T 6, **23+**; O 1, **23+**.

Chemiker-Zeitung. 1877. **54.**
N 1, **4–52**; N 2, **47+**; T 5, **46+**.

Chemische Fabrik. 1928. **28.**
N 1, **1+**; N 2, **1+**; A 1, **1+**; T 1, **1+**.

Chemische Industrie. 1878. **53.**
A 1, **1+**; T 1, **1+**; T 5, **44+**; Tn 3, **1–41, 43+**.

Chemisches Zentralblatt. 1830. **101.**
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N 2, **1+**; Tn 3, **25–42**.

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V 1, **1+**; T 2, **4+**.

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V 2, **89+**; N 3, **81+**; A 1, **89+**; T 1, **83+**; O 1, current.

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V 1, **140+**; K 3, **105, 115–116, 118, 120, 122–133, 135+**.

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S 2, **2–16**; A 1, **1–16.**

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O 4, **19+**.

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L 2, **4+**; T 1, **2+**; T 4, **10+**; O 4, **10+**; Ar 1, current.

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V 1, **187–192, 196, 198, 200**; T 5, **1+**.

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V 2, **13+**; N 3, **1924+**; T 4, **4–11.**

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Tn 3, **1+**.

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V 1, **121–157, 159, 165+**; V 2, **142–145, 154–157, 160–179**; N 1, **1+**; N 2, **176–187**; F 1, **170+**; A 1, **156+**; L 1, **1+**; L 2, **100–114, 116+**; T 1, **1+**; T 2, **172+**; T 4, **164–185**; T 5, **1–153, 157+**; O 1, **1+**; Ar 1, **1+**; K 3, **134+**; Tn 1, **86+**; Tn 3, **1–160, 162+**.

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Cotton. **1–15,** 1899–1908, **73+**; 1908+. **94+.**
N 3, **87+**; S 2, **87+**; T 6, **89+**.

Cotton Oil Press. 1917. **14.**
N 3, **3, 8+**; L 1, **1+** (inc.); T 3, **6–13**; T 4, **1–13**; O 3, **4+**.

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T 2, **1–13.**

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V 3, **1+**; T 9, current; K 1, current; Tn 2, **1–3, 41+**.

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V 3, **8+**; T 9, current; K 1, current; Tn 2, **25–41, 44+**.

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K 1, **1–2**; Tn 2, **17–19, 21–32.**

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N 2, **1+**; A 2, **114–117**; K 1, **1+**; Tn 2, **98+**; Tn 3, **1+**.

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O 3, current.

Deutsche Landwirtschaftliche Rundschau.
O 3, current.

Deutsche medizinische Wochenschrift. 1875. **56.**
V 1, **2, 4, 25–40**; V 3, **6+**; N 2, **1+**; A 2, **33–34, 40, 54+**; T 2, **17+**; K 1, **55+**; K 3, **37+**; Tn 2, **36+**; Tn 3, **3+**.

Dinglers polytechnisches Journal. 1820.
V 1, **179–182, 207–294.**

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V 3, **64+**; N 1, **1–55, 61, 72**; S 3, **70+**; F 1, **14–58, 60–61, 66, 70+**; M 1, current; T 1, **47+** (inc.); T 6, **65+**; O 1, **72+**; Tn 2, **57–59, 67+**; Tn 3, **21–40, 42, 46–52.**

Dyestuffs. 1898. **31.**
N 1, **7–29**; N 3, **25+**; S 2, **23+**; O 3, **27+**; Ar 1, current.

Ecology. 1920. **11.**
V 2, **1**+; V 9, **1**+; N 1, **1**+; N 2, **1**+; N 3, **1**+; S 2, **5**+; G 1, **1**+; F 1, **1**+; A 4, **1**+; M 2, **1**+; L 2, **1**+; T 1, **1**+; T 8, **3**+; T 10, **1**+; O 1, **1**+; O 3, **7**+; Ar 1, **1**+; K 3, **1**+; Tn 1, 9+.

Economic Geology. 1905. **25.**
V 1, **1–20, 23**+; V 2, **1**+; N 1, **1–20**; N 3, **21**+; S 2, **1, 21–23**; A 1, **1**+; A 2, **9, 11, 18, 22**+; M 2, **1**+; L 1, **1**+ (inc.); L 3, **1**+; T 1, **1**+; T 4, **1**+; T 6, **7**+; T 10, **1**+; T 11, current; O 1, **1**+; O 3, **23**+; O 4, **1**+; O 5, **23–24**; Ar 1, **1**+; K 3, **1–4, 6–12, 14–16, 18–20, 22**+; Tn 1, **1**+; Tn 3, **1**+.

Economic Proceedings of the Royal Dublin Society. 1899.
T 1, **1**+; O 1, **6**+.

Edinburgh Medical Journal. 1855. [3] **37.**
V 3, **1**+; S 3, **24**+; T 2, **1**+; T 9, current; O 2, **32–36**; Tn 2, **33**+; Tn 3, **23–25, 27–39, 40–41**; [2] **1–10, 12**; [3] **1, 4–13, 16**.

Electric Journal. 1904. **27.**
V 1, **1–22, 27**+; V 2, **1**+; N 1, **1**+; N 2, **21**+; N 3, **1**+; S 2, **1, 3**+; G 1, **26**+; G 2, **1**+; F 1, **12, 19**+; A 2, **1, 3–17, 19–20, 25**+; M 2, **3–17, 19**+; L 1, **1**+ (inc.); T 1, **23**+; T 4, **3**+; O 1, **7, 11**+; O 3, **12**+; Ar 1, **22**+; K 2, **22**; K 3, **2–9, 11–12**; Tn 1, **2**+; Tn 3, **25**+; Tn 5, **1–5, 13**.

Electric Railway Journal. 1884. **74.**
V 1, current; V 2, **32, 35–36, 38–39, 49, 61**; N 2, **63**+; S 2, **38**+; G 2, **32**+; G 4, **57**+; A 2, **1909**+; L 2, **10**+; T 1, **74**+; T 3, current; T 4, **33–46** (inc.), **47**+; T 6, **45**+; T 11, current; O 3, current; K 3, **32–47, 72–73**; Tn 6, current.

Electrical News. 1891.
T 5, current.

Electrical Review. 1872. **106.**
V 1, **1–83**; N 3, **41–79**; F 1, **57, 59–67**; A 2, **71–77**; L 2, **23–31, 34**; T 1, **86**+; O 1, **74–77**; O 3, **70–75, 79**; Ar 1, **61**+; K 3, **43–48**.

Electrical World. 1883. **95.**
V 1, **23**+; V 2, **21–24, 26–27, 30**+; V 5, **84–94**; V 8, current; N 1, **21**+; N 2, **38**+; N 3, **40**+; S 2, **33**+; G 1, **33**+; G 2, **27–31, 35–38, 41**+; G 4, **45**+; F 1, **35–79** (inc.), **81**+; A 2, **9–42, 48–72, 74**+; M 1, current; M 2, **5–10, 41–77, 91**+; L 1, **38–41, 47, 50–62, 64**+; T 1, **10–58, 60**+; T 3, **47**+; T 4, **37–56, 58–63, 66**+; T 5, **1**+; T 6, **18**+; T 10, **46**+; T 11, **37–41, 44**+; O 1, **52–58, 60–76, 79–88, 92**+; O 3, **31**+; O 4, **83**+; Ar 1, **37**+; K 2, **33–46**; K 3, **92**+; Tn 1, **34–63, 65**+; Tn 3, **65**+; Tn 4, **93**+; Tn 5, **31**+; Tn 6, **85–92**; Tn 8, current.

Electrician. 1878. **104.**
V 1, **22–25, 28–68**; V 2, **64–68**; N 1, **66**+; G 2, **63**+; F 1, **55**+, L 2, **45**+; T 1, **12**+; T 5, **1**+; O 3, **44–45**; Ar 1, **44**+; Tn 1, **35**+.

Elektrotechnische Zeitschrift. 1880. **51.**
N 1, **28**+; T 5, **1**+.

Endocrinology. 1917. **14.**
V 1, **1**+; V 3, **1**+; N 2, **3**+; S 3, **2**+; T 5, **1**+; T 9, current; O 2, **2–13**; O 3, **10**+; Ar 2, **1**+; K 1, **1**+; K 3, **12**+; Tn 2, **2**+; Tn 3, **1**+.

Endokrinologie. 1928. **6.**
V 1, **1**+; N 2, **1**+; T 1, **2**+; K 1, **1**+; K 2, **1929**+.

Engineer. 1856. **149.**
V 1, **1–73, 149**+; V 2, **123**+; N 3, **40–43**; S 2, **39–40**; A 2, **29, 36, 75–78, 145**+; L 1, **41–44**; T 5, **1**+.

Engineering. 1866. **129.**
V 1, **1**+; V 2, **60, 89–94, 97**+; N 1, **110**+; N 3, **65–66, 122**+; G 2, **81**+; G 4,

65–67, 73–77, 79, 81+; F 1, **80–114, 116+**; A 2, **123+**; L 1, **124+**; L 2, **39–78, 81+**; T 1, **3+** (inc.); O 3, **67–72**; Ar 1, current; K 2, **27–43**; K 3, **66+** (inc.); Tn 1, **5+**; Tn 3, **45–50, 85–91, 94–95, 97+**; Tn 5, **4–22.**

Engineering and Contracting. 25 (1906). **69.**
V 1, **69+**; V 2, **28, 31+**; V 5, **62–70**; N 2, **60+**; S 2, **67+**; G 4, **59+**; F 1, **36+**; A 2, **33–56, 58+**; L 1, **66+**; L 2, **57+**; T 4, **29+**; O 3, **69+**; Tn 5, **31–59, 61, 64+.**

Engineering and Finance. **22.**
T 1, **2+.**

Engineering and Mining Journal-Press. 1886. **129.**
V 1, **126+**; V 2, **86+**; V 6, **79+**; V 7, **117+**; N 1, **111+**; N 3, **127+**; S 2, **75+**; G 2, **83+**; G 4, **79+**; F 1, **103–108, 110+**; A 1, **1+**; A 2, **48–103, 105–108, 112+**; M 2, **70, 79–102, 105–109, 113–114, 116+**; L 1, **124+**; L 2, **101+**; T 1, **51–61, 63–91, 93–95, 97+**; T 3, **102–112, 124–128**; T 4, **79+**; T 5, **1+**; T 6, **87+**; T 10, **55, 69+**; T 11, **88+**; O 1, **15, 19–100, 108+**; O 4, **95+**; Ar 1, **1+**; K2, **15–17**; K 3, **105–118, 121–122, 125+**; Tn 1, **85+**; Tn 3, **44–96**; Tn 5, **85+**; Tn 8, current.

Engineering Journal. 1918. **13.**
T 4, **5+.**

Engineering News-Record. 1874. **104.**
V 1, **8, 16–17, 30+**; V 2, **13–15, 17–77, 78+**; V 5, **92–103**; V 6, **67+**; V 8, **88–93**; N 1, **1917–1922**; N 3, **39–65, 67–74, 91+**; S 2, **51+**; G 1, **19+**; G 2, **53+**; G 4, **78+**; F 1, **78+**; A 1, **1+**; A 2, **21+**; M 1, current; M 2, **9–85, 88+**; L 1, **35–36, 40–41, 43–83, 86+**; L 2, **78+**; L 3, **55+**; T 1, **2+**; T 3, **78+**; T 4, **7+**, T 5, **1+**; T 6, **53+**; T 10, **55+**; T 11, **45–50, 52+**; O 1, **68, 79–80, 82–85, 88–91, 97, 100+**; O 3, **77+**; O 4, **82+**; Ar 1, **8+**; K 2, **44–75, 77–86, 88+**; K 3, **78+**; Tn 1, **36+**; Tn 3, **78–93, 95+**; Tn 4, **104+**; Tn 5, **78+**; Tn 6, **94, 97+**; Tn 8, current.

Engineering Progress (Berlin). 1920.
A 2, **1927–1928.**

Engineering World. 1907.
T 4, **14–27**; T 6, **14–34**; O 4, **24–34**; Ar 1, current.

Entomological News. 1890. **41.**
N 3, **34+**; S 2, **3+**; A 4, **1+**; M 2, **4+**; L 1, **25+**; T 1, **1+**; T 5, **1+**; Ar 1, current.

Ergebnisse der Anatomie und Entwicklungsgeschichte. 1891.
T 5, **1+**; Tn 3, **1+.**

Ergebnisse der Physiologie. 1902.
V 3, **14+**; N 2, **1+**; Tn 2, **26+**; Tn 3, **1–21, 23+.**

Ernährung der Pflanze. 1905.
M2, current; O 3, **25+.**

Experiment Station Record. 1892. **62.**
V 2, **1+**; V 3, **35+**; V 8, **24+**; V 9, **39+**; N 1, **1+**; N 3, **1+**; S 2, **1+**; G 1, **1+**; G 3, current; F 1, **16+**; A 4, **1+**; M 2, **1+**; L 1, **3, 5–8, 10, 12+**; T 1, **1+**; T 2, **24, 37+**; T 4, **1+**; T 5 (inc.); T 6, current; T 10, **38+**; T 11, **24+**; O3, **1+**; Ar 1, **1+**; Tn 1, current; Tn 3, current; Tn 4, **17+**; Tn 5, **17+**; Tn 6, **1+.**

Explosives Engineer. 1923. **8.**
N 3, **1+**; T 10, **6+**; O 3, **5+**; O 4, **1+**; Tn 3, **1–6.**

Facts about Sugar. 1916.
L 1, **19+.**

Far Eastern Review. 1904. **26.**
T 1, **16+.**

Farming in South Africa. 1927. **4.**
V 2, **1**+; N 3, **1**+; S 2, **4**+; F 1, **1**+.

Fermentforschung. 1914. **11.**
N 2, **1**+; O 2, **10**+.

Fertilizer Green Book. **11.**
V 2, **1**+; S 2, **6**+; O 3, **7**+.

Flora. 1818. [n. s.] **24.**
N 1, **93–123**; N 2, **121–122**; T 1, **1**+ (inc.); O 1, **122**+.

Folia Haematologica. 1904. **40.**
V 1, **9, 21, 24–25, 27**; O 2, **1–39**; Tn 3, **9**+.

Food Industries. **2.**
L 1, **1**+.

Fortschritte der Medizin. 1883. **48.**
N 2, **1**+.

Foundry. 1892. **58.**
N 3, **48**+; S 2, **54**+; F 1, **57**+; A 2, **42**+; L 1, **32, 38–40**; L 2, **14**+; T 4, **51**+; T 6, **11–41, 56**+; T 10, **48**+; T 11, **42**+; K 2, **1908**+; K 3, **45, 47–50**; Tn 5, **32–47**; Tn 6, **43–44, 53–56.**

Frankfurter Zeitschrift für Pathologie. 1907. **39.**
N 2, **1**+; Tn 3, **1–36.**

Fruit Products Journal and American Vinegar Industry. 1921. **9.**
N 3, **6–7**; F 1, **1**+.

Fuels and Furnaces. 1923. **8.**
A 2, **1**+, Tn 8, current.

Forging, Stamping, and Heat Treating. 1915.
T 1, **7, 11–13.**

Gas Age-Record. 1883. **65.**
A 2, **48**+; T 6, **61**+; T 11, **43**+; O 1, **51–53, 55, 57**+; O 4, **31**+; K 2, **1928**+; Tn 6, **63**+.

Gas Industry. 1901.
O 4, **5–21.**

Gas Journal. 1849. **189.**
A 2, **189**+; T 3, **181–188**; O 1, **145–147, 149–167, 169–179, 182**+.

Gas und Wasserfach. 1858. **73.**
T 1, **44**+.

Gazzetta chimica italiana. 1871. **60.**
N 1, **1**+; N 2, **1–34, 36–49, 55–58**; A 1, **1**+; T 1, **1**+; T 5, **48**+.

General Electric Review. 1903. **33.**
V 1, **5, 25, 33**+; V 2, **18**+; N 1, **13**+; N 2, **26**+; N 3, **12**+; S 2, **29**+; G 2, **16**+; G 4, **19**+; F 1, **16–18, 20–22, 25–28, 32**+; A 1, current; A 2, **10**+; L 1, **30**+; T 1, **20**+; T 4, **16–19**; T 10, **22**+; T 11, **29**+; O 1, **10, 20**+; O 3, **18**+; O 4, **29**+; O 5, **30–33**; Ar 1, **13**+; K 2, **31**+; K 3, **10, 13, 15–18, 29**+; Tn 1, **13**+; Tn 3, **31**+.

General Science Quarterly. 1916.
N 1, **1**+; N 3, **1–5, 7**+; L 1, **8**+; T 1, current; O 1, **1–5**; Ar 1, current.

Genie civil. 1880. **96.**
A 2, **92**+.

Geological Magazine. 1864. **67.**
V 1, **1**+; N 1, **1**+; O 1, **5–8, 58**+; L 1, **64**+; Ar 1, **1**+; K 3, **66**+; Tn 1, **5**+; Tn 3, **1**+.

Geological Survey of Great Britain, Publications.
Tn 3, partial set.

Gesundheits-Ingenieur. 1878.
T 1, **1**+.

Giornale di chimica industriale ed applicata.
A 1, **1**+.

Glasgow Medical Journal. 1828. **32.**
V 3, **103**+; Tn 3, **19–78, 80**+.

Glass.
A 1, current.

Glass Container. 1921. **9.**
V 2, **2–4** (inc.); V 8, current; A 1, **1**+; A 2, **1**+; L 1, **7**+; T 10, **8**+; O 1, current; Ar 1, current; K 2, **3**+ (inc.).

Glass Industry. 1920. **11.**
O 4, **5**+.

Hahnemannian Monthly.
A 1, current.

Heating and Ventilating Magazine. 1904. **27.**
V 2, **26**+; N 3, **17**+; A 2, **25**+; T 1, **13**+; T 5, **14**+; T 11, **18**+; O 1, **11, 13, 19–20, 23**+; Ar 1, current; K 2, **22**+; K 3, current; Tn 1, **16**+; Tn 3, **26**+; Tn 5, **20**+; Tn 6, **22–25.**

Heil- und Gewürz-Pflanzen. 1917. **12.**
T 2, **9.**

Helvetica Chimica Acta. 1918. **13.**
N 1, **1**+; N 2, **1**+; G 1, **1**+; T 1, **1**+; Tn 3, **7**+.

Hilgardia. 1925. **4.**
V 2, **1**+; S 2, **3**+; F 1, **1**+; A 2, **1**+; A 4, **1**+; L 3, **1**+; T 1, **4**+; O 3, current.

Home Economist and American Food Journal. 1923.
V 5, **20–25**; N 3, **20**+; L 1, current; O 3, current; Ar 1, current; Tn 1, **17**+; K 3, **6**+.

Hygienische Rundschau. **1–32.** 1891–1922.
Tn 3, **1–32.**

Ice and Refrigeration. 1891. **78.**
V 2, **75**+; N 3, **76**+; F 1, **70**+; L 1, **48–51, 73**+; L 2, **66**+; T 4, current; T 6, **70**+; T 11, current; O 3, **70**+; K 2, **48–68**; K 3, **22**+ (inc.); Tn 3, **72**+.

Ice Cream Trade Journal. 1905. **26.**
V 2, **24**+; G 1, **23**+; K 1, current; Tn 1, **21**+.

Illinois Biological Monographs.
V 2, **6–11**; V 3, **1–10**; T 1, **11**+; T 2, **1**+; T 5, current; O 3, current; K 3, **1**+.

India Rubber World. 1889. **82.**
A 1, current; A 2, **75**+; K 3, **66, 72, 77**+.

Indian Journal of Medical Research. 1913. **17.**
V 3, **10**+; N 2, **1**+; S 3, **8**+; T 5, **1**+; Tn 3, **8**+.

Indian Journal of Physics. **4.**
V 1, **3–8**; F 1, **1930**+; T 1, **4**+; T 5, **1**+; O 1, **1**+.

Indian Medical Gazette. 1866. **65.**
V 3, **62**+; N 2, **1**+; T 5, **63**+.

Industrial and Engineering Chemistry. 1909. **22.**
V 1, **1**+; V 2, **1**+; V 3, **1**+; V 4, **1**+; V 6, **1–2, 6**+; V 8, **14**+; N 1, **1**+; N 2, **1**+; N 3, **1**+; N 4, **1**+; S 1, **1**+; S 2, **1**+; G 1, **1**+; G 2, **1**+; G 3, **12**+;

G 4, **3+**; F 1, **1+**; A 1, **1+**; A 2, **6+**; A 4, **1+**; M 1, **1+**; M 2, **1+**; L 1, **1+**; L 2, **1+**; L 3, **3–16**; T 1, **1+**; T 2, **1+**; T 3, **1+**; T 4, **1+**; T 5, **1+**; T 6, **1+**; T 7, **1+**; T 8, **1+**; T 10, **1+**; T 11, **4+**; O 1, **1+**; O 2, **17+**; O 3, **1+**; O 4, **1+**; Ar 1, **1+**; K 2, **13+**; K 3, **1+**; Tn 1, **1+**; Tn 2, **1+**; Tn 3, **1+**; Tn 5, **1+**; Tn 6, **17–20**; Tn 8, current.

Industrie chimique.
A 1, **1+**.

Instruments. 1928. **3.**
V 2, **1+**; A 2, **1+**; L 1, **2+**; L 2, **1+**.

International Journal of Public Health. **1–2.** 1920–1921.
V 1, **1–2.**

International Review of Agriculture. 1910. **21.** From 1923–1926, called *International Review of the Science and Practice of Agriculture.*
V 2, **1+**; G 1, **4+**; F 1, **1+**; L 1, current; L 3, **18+**; T 1, **1+**; O 3, **7–17**; Ar 1, current; Tn 1, **1+**.

International Sugar Journal. 1899. **32.**
L 1, partial set; L 2, **5+**; L 4, **4–6, 27+**.

Iowa State College Journal of Science. 1927. **4.**
A 2, **1+**; L 1, **1+**; T 1, **4+**; O 3, current.

Iron Age. 1857. **125.**
V 6, **78+**; S 2, **121+**; G 4, **85+**; F 1, **115+**; A 1, **1+**; A 2, **79–103, 105+**; T 1, **94+**; T 4, **97+**; T 5, **45+**; T 6, **80+**; T 10, **103+**; T 11, **108+**; O 1, **44–95, 105–122**; Ar 1, current; K 2, **1919+**; K 3, **100, 103, 105, 107, 109+**; Tn 5, **1+**; Tn 8, current.

Iron and Coal Trades Review.
A 1, **1+**.

Iron and Steel Institute (London), *Carnegie Scholarship Memoirs.* 1909.
N 2, **1+**; A 1, **1+**; Tn 3, **1+**.

Iron and Steel of Canada.
A 1, **1+**.

Iron Trade Review. 1867. **86.**
A 2, **54+**; T 4, **52–86**; O 1, **68–75**; O 4, **86+**; K 3, **37–40, 42–46, 48–58, 83+**.

Isis. 1913. **13.**
V 8, **2+**; T 5, current; O 1, **6+**; K 1, current.

Jahrbuch für Kinderheilkunde und physische Erziehung. 1857. **126.**
V 1, **1–8**; [2] **1–66**; N 2, **1+**; T 1, [2] **1–7**; Tn 3, **3–7**, [2] **1–21, 23–28, 31, 33–81, 84, 87, 94, 110+**.

Jahrbuch für Radioaktivität und Elektronik. **1–20.**
T 5, **1–20**; Ar 1, **1–11.**

Jahrbücher für wissenschaftliche Botanik. 1858. **72.**
N 1, **37+**; N 2, **66–69**; L 1, **47–56**; T 1, **30+**; O 1, **67+**.

Jahresbericht der Pharmazie. 1866.
O 1, **3, 5–11, 13–53, 59+**.

Japan Medical World. 1921. **10.**
V 3, current; N 2, **1+**; T 2, **1–7**; O 2, **4–9**; Ar 2, **1+**; K 1, current; Tn 3, **2+**.

Japanese Journal of Astronomy and Geophysics. 1922. **7.**
V 1, **1.**

Japanese Journal of Botany. 1922. **5.**
V 1, **1–4**; G 1, **1+**; L 1, current; O 3, **1+**; Ar 1, current.

Japanese Journal of Chemistry. 1922.
V 1, **3+**; N 1, **1+**; N 2, **1+**.

Japanese Journal of Engineering. 1921. **7** (1929).
V 1, **7**; N 1, **1+**; G 1, **1+**; L 1, current.

Japanese Journal of Mathematics. 1924.
T 1, **1+**.

Japanese Journal of Medical Sciences. 1922.
N 2, **1+**; G 1, **1+**.

Japanese Journal of Physics. 1922. **5** (1929).
N 1, **1–4**; G 1, **1+**; L 1, current; O 1, **1–2**; Ar 1, current.

Japanese Journal of Zoölogy. 1922.
V 1, **2+**; G 1, **1+**; M 1, current; L 1, current; O 1, **1+**; Ar 1, current.

Japanese Medical Literature. **1–6.** 1916–1921.
V 1, **2–6.**

Journal and Proceedings of the Royal Society of New South Wales.
A 1, current.

Journal de chimie physique. 1903. **27.**
N 1, **1+**; A 1, **11+**; T 1, **1+**; T 5, **22+**; O 1, **1+**; Ar 1, **1+**.

Journal de l'école polytechnique. 1795.
Tn 3, **1–64.**

Journal de pharmacie et de chimie. 1909. [8] **11.**
N 1, **1842–1897**; F 1, **1–** [8] **6**; O 1, **1–6**; [2] **2–24**; [3] **1–46**; [4] **1–30**; [5] **1–30**; [6] **1–30**; [7] **1–16**; [8] **5+**.

Journal de physique et le radium. 1872. [7] **1.**
N 2, **4–9**; G 2, **9+**; F 1, [4] **4–9**; [5] **1–4**; [6] **7+**; T 1, **1, 4, 6–7, 9+**; T 5, **1+**; O 1, **1–9**; Tn 3, **10+**; K 3, **3+**.

Journal de physiologie et de pathologie générale. 1899. **28.**
V 1, **1–6**; [2] **1–3**; T 2, **16, 19–20, 23+**.

Journal für Landwirtschaft. 1853. **77.**
V 2, **54+**; L 1, partial set.

Journal für praktische Chemie. 1834. **126.**
V 1, **1+**; N 1, **1+**; N 2, **1–115, 117+**; A 1, **1918+**; M 2, **1+**; L 2, **1857–1879**; A 4, **35–54**; T 1, **1+**; T 5, **1–109**; Tn 3, **95–98, 102+**.

Journal of Agricultural Research. 1913. **40.**
V 2, **1+**; V 8, **1+**; N 1, **1+**; N 2, **1+**; N 3, **1–17, 19+**; S 2, **1+**; G 1, **1+**; G 3, **38+**; G 4, **1+**; F 1, **1+**; A 2, **1+**; A 4, **2+**; M 1, current; M 2, **1+**; L 1, **1+**; L 3, **1+**; T 4, **1+**; T 5, **1–12, 15–29, 31+**; T 8, **38–40**; T 10, **33+**; T 11, **1913+**; O 1, **1–20, 23, 25+**; O 3, **1–12, 14+**; Ar 1, **1+**; Ar 2, **1+**; K 2, **1+**; K 3, **1+**; Tn 1, **1+**; Tn 3, **1+** (inc.); Tn 4, **1+**; Tn 5, **32+**; Tn 6, **1+**.

Journal of Agricultural Science. 1905. **20.**
V 2, **2+**; N 3, **14+**; S 2, **1+**; F 1, **1+**; A 4, **1+**; M 2, **1+**; T 4, **1+**; L 1, **16+**, O 3, **1+**; Ar 1, **1+**; Tn 1, **1+**.

Journal of Bacteriology. 1916. **19.**
V 1, **1+**; V 2, **1+**; V 3, **1+**; V 8, **6, 8+**; V 9, **1+**; N 1, **2+**; N 2, **9+**; N 3, **1+**; S 3, **1+**; G 1, **1–5**; F 1, **1+**; A 2, **11+**; A 4, **2+**; L 1, **17+**; T 1, **1+**; T 2, **1+**; T 4, **1–16**; T 5, **5, 7, 9–17**; T 9, current; O 2, **1+**; O 3, **2–3, 10+**; Ar 1, **1+**; Ar 2, **1+**; K 2, **1+**; K 3, **1+**; Tn 1, **1+**; Tn 2, **1+**; Tn 3, **1+**.

Journal of Biochemistry (Japan). 1922. **12.**
N 2, **1+**; T 2, **1–5, 8+**; O 2, **1+**; Tn 2, **1+**; Tn 3, **1+**.

Journal of Biological Chemistry. 1905. **85.**
V 1, **1+**; V 2, **1–10, 29+**; V 3, **1+**; V 8, **49–50**; N 1, **1+**; N 2, **1+**; N 3, **1+**; S 1, **1913, 1922–1929**; S 2, **13+**; S 3, **1+**; G 1, **29+**; G 5, **1+**; F 1, **1+**; A 1, **1+**; A 2, **1+**; A 4, **1+**; M 1, current; M 2, **1+**; L 1, **1+** (inc.); T 1, **1+**;

T 2, 1+; T 4, 1+; T 5, 1+; T 9, current; O 1, 1–50, 52, 57+; O 2, 1+; O 3, 1+; Ar 1, 1+; Ar 2, 1+; K 1, 47+; K 3, 1+; Tn 1, 1+; Tn 2, 1+; Tn 3, 1+.

Journal of Biophysics (Japan). 1923.
T 2, 1; K 2, 1+.

Journal of Cancer Research. 1916. **14.**
V 1, 2–8, V 3, 1+; N 2, 1+; S 3, 1+; A 2, 1–7, 9+; T 2, 1+; T 5, 1–7; T 9, current; O 2, 1+; Ar 2, 1+; K 2, 5+; Tn 2, 1+; Tn 3, 1+.

Journal of Chemical Education. 1924. **7.**
V 1, 5+; V 3, 1+; V 4, 1+; V 5, 5+; V 7, 1+; V 9, 3+; N 1, 1+; N 2, 1+; N 3, 1–3, 5+; N 4, 1+; S 1, 1+; S 2, 1+; S 3, 6+; G 2, 1+; G 3, 6+; F 1, 1+; A 1, 1+; A 2, 6+; M 2, 1+; L 1, 1+; L 2, 1+; T 1, 1+; T 2, 1–2, 4–5; T 4, 3+; T 5, 1+; T 7, 6+; O 1, 1–2, 4+; O 3, 2+; O 5, 4–7; Ar 1, 1+; K 1,2 +; K 3, 1+; Tn 1, 1+; Tn 3, 1+.

Journal of Clinical Investigation. 1924. **8.**
V 1, 5+; V 3, 1+; N 2, 1+; S 3, 5+; T 2, 1+; T 9, current; O 2, 1+; K 1, 1+; K 3, 1+; Tn 2, 1+; Tn 3, 1+.

Journal of Comparative Neurology. 1891. **50.**
V 1, 26+; V 9, 31–35; N 1, 21–48; N 2, 1+; F 1, 26, 28, 30–32, 46+; L 2, 3+; T 1, 1+; T 2, 1–2, 8–9, 15+; T 5, 25+; O 2, 16–21, 23, 25+; K 3, 26–27, 29–30, 33–35; Tn 2, 26+; Tn 3, 1–23 (inc.), 24+.

Journal of Comparative Pathology and Therapeutics. 1888. **43.**
V 2, 42+; N 3, 42+; S 2, 18–21; L 1, 43+; T 4, 37–41; Ar 1, current; K 3, 24–36.

Journal of Dairy Science. 1917. **13.**
V 2, 1+; N 3, 7+; S 2, 10+; G 1, 1+; F 1, 1+; A 4, 1+; M 2, 2+; L 1, 1+; O 3, 1+; Ar 1, current; K 3, 1+; Tn 1, 1+.

Journal of Dental Research. 1919. **10.**
V 1, 1–6; V 3, 1+; S 3, 1–3; T 2, 1, 5; K 1, current; Tn 2, 1+.

Journal of Economic Entomology. 1908. **23.**
V 2, 1+; N 2, 2+; N 3, 17+; S 2, 1+; G 1, 1+; F 1, 1+; A 4, 1+; L 1, 1+; T 1, 1+; T 4, 1+; T 5, 1+; O 1, 10+; Ar 1, 1+.

Journal of Electricity. 1895.
N 2, 53+; N 3, 22–28, 30+; T 1, 32+; T 5, 1+; T 10, 42+; O 1, 42–45.

Journal of Engineering Education. 1910.
V 1, 18+; V 2, 15+; S 2, 19+; F 1, 15+; A 2, 20+; T 1, 15+; T 4, current; T 5, 17+; O 1, 1–10, 15–16, 18+; K 1, 18+; Tn 1, 17+; Tn 3, 15+.

Journal of Experimental Biology. 1923. **7.**
N 2, 2+; N 3, 1+; L 1, 1+ (inc.); T 5, 1+; O 1, 1+; Ar 1, current; K 3, 1+; Tn 1, 1+; Tn 3, 1+.

Journal of Experimental Medicine. 1896. **51.**
V 1, 1+; V 2, 40–44, V 3, 1+; V 8, 13, 15; N 1, 1+; N 2, 1+; N 3, 43+; S 3, 19, 23+; F 1, 31+; A 2, 9–33, 35+; M 1, current; T 1, 1+; T 2, 1+; T 4, 34+; T 5, 1+; T 9, current; O 2, 10–11, 13–16, 18, 20–28, 31+; Ar 1, 1+; Ar 2, 1+; K 1, 13+; K 3, 2+; Tn 2, 7+; Tn 3, 1+.

Journal of Experimental Zoölogy. 1904. **55.**
V 1, 1–10, 12+; V 2, 1+; V 3, 41+; V 8, 32+ (inc.); V 9, 31+; N 1, 1+; N 2, 1+; N 3, 37+; S 2, 49+; G 1, 1+; F 1, 6–24, 28–33, 35–43, 47–50, 52+; M 1, current; L 1, 1–36, 55+; L 2, 20+; T 1, 1–39, 41+; T 2, 1+; T 4, 1+; T 5, 16+; T 7, 1+; T 8, 25+; O 1, 1+; O 3, 39+; O 5, 47–49; Ar 1, 1+; K 3, 21–27, 31–33, 35+; Tn 1, 1+; Tn 2, 1+; Tn 3, 1+.

Journal of Forestry. 1902. **28.**
V 2, 27+; N 3, 22+; G 1, 15+; L 4, 20+; T 4, 14+; Ar 1, current.

Journal of General Physiology. 1918. **13.**
V 1, 1+; V 3, 1+; N 1, 1+; N 2, 1+: G 1, 1+: A 4, 13+; M 2, 1+; L 1, 9+; T 1, 1+; T 2, 1+; T 4, 1+; T 5, 1+; T 9, current; Ar 2, 1+; K 3, 1+; Tn 1, 1+; Tn 2, 1+; Tn 3, 1+.

Journal of Genetics. 1910. **22.**
V 2, 1+; V 8, 10+; N 2, 1–2, 13, 15–18; S 2, 1+: F 1, 1+; L 1, partial set; T 1, 1+; T 5, 5+; O 1, 1–2, 5–10, 13+; O 3, 5–6, 19+; Ar 1, current; Tn 1, 1+.

Journal of Geology. 1893. **38.**
V 1, 1–31, 38+; N 1, 1+; N 2, 13–19; N 3, 34+; S 2, 13+; G 1, 32+; A 1, 1+; M 1, current; M 2, 4–6, 13, 15+; L 1, 1–6, 8, 10+; L 2, 23+; L 3, 8+; T 1, 1+; T 4, 12+; T 6, 34+; T 8, 33+; T 10, 27+; T 11, 27+; O 1, 1–35; O 3, 34+; O 4, 32+; O 5, 34–36; Ar 1, current; K 3, 1–11, 13–14, 16–17, 22–26, 28+; Tn 1, 1+; Tn 3, 1+.

Journal of Home Economics. 1909. **22.**
V 2, 12+; V 8, 14+; V 9, 8+; N 3, 16+; G 1, 1+; G 4, 3+; A 2, 7+; M 1, current; M 2, 1+; L 1, 1+ (inc.); T 1, 4+; T 5, 1–2; T 6, 11+; T 7, 8+; T 10, 16+; T 11, 7+; O 1, 8+; O 3, 1–20; O 5, 20–22; K 2, 1–8, 10; Ar 1, 8+; K 3, 1+; Tn 1, 2+; Tn 5, 7+; Tn 6, 7–20.

Journal of Hygiene. 1901. **29.**
V 1, 4, 9–26; V 3, 11+; S 3, 29+; M 1, current; T 1, 1+; T 2, 1+; T 5, 20+; T 9, current; O 2, 16+; K 3, 18+; Tn 1, 19+; Tn 3, 1+.

Journal of Immunology. 1916. **18.**
V 1, 1+; V 2, 11+; V 3, 1+; N 1, 1+; N 2, 1+; N 3, 19+; S 3, 2+; A 2, 16+; M 1, current; L 1, 13+; T 1, 1+; T 2, 1+; T 4, 1+; T 5, 1–7, 9+; T 9, current; O 2, 1+; Ar 1, current; Ar 2, 1+; K 1, 1+; K 3, 2+; Tn 1, 1+; Tn 2, 1+; Tn 3, 1+.

Journal of Industrial Hygiene. 1919. **12.**
V 1, 1+; V 3, 1+; N 1, 2–3; N 2, 1+; S 3, 1–2; A 2, 9+; T 1, 1+; T 2, 1–3, 7+; O 2, 1+; K 1, 2+; Tn 1, 4+.

Journal of Infectious Diseases. 1904. **46.**
V 1, 1+; V 2, 18+; V 3, 1+; N 1, 1–15; N 2, 1+; N 3, 36+; S 3, 1, 9, 12+; F 1, 39+; A 2, 16–34, 36+; A 4, 5–10, 12+; M 1, current; M 2, 1+; L 1, 44+; T 1, 1–7, 9, 12+; T 2, 1+; T 4, 1+; T 5, 34+; T 9, current; O 2, 13–16, 18, 20+; O 3, 1–31; Ar 1, current; Ar 2, 1+; K 2, 8+; K 3, 1+; Tn 1, 28+; Tn 2, 1+; Tn 3, 1+.

Journal of Laboratory and Clinical Medicine. 1915. **15.**
V 1, 1–10, 14+; V 3, 1+: N 1, 1+; N 2, 1+; S 3, 1+; A 2, 2+; T 1, 1–2, 4–5, 7+; T 2, 1+; T 9, current; O 2, 6+; Ar 1, current; Ar 2, 1+; K 1, 1+; K 3, 8+; Tn 2, 1+; Tn 3, 1+.

Journal of Mathematics and Physics. 1921. **9.**
N 1, 2+; T 1, 1+; T 5, 1+.

Journal of Medical Research. **1–44.** 1896–1924. Superseded by *American Journal of Pathology.*
V 3, 11+; F 1, 42–44; A 2, 31–37, 39–43; O 2, 6–44; Ar 2, 1901–1924; Tn 2, 1–29; Tn 3, 6–44.

Journal of Metabolic Research. 1922.
V 1, 5–8; V 3, 1+; N 1, 2–8; N 2, 1+; F 1, 7+; A 4, 4–8; T 2, 1+; T 9, current; O 2, 1+; O 3, 5+; K 1, current; Tn 2, 2+; Tn 3, 1+.

Journal of Morphology and Physiology. 1887. **49.**
V 1, 1–17, 19+; V 3, 27+; V 9, 32+; N 1, 27–46; N 2, 1+ (very inc.); N 3, 1923+; G 1, 19+; F 1, 20–21, 24–37, 40+; L 1, 1+; L 2, 9–17, 32+; T 1, 1+;

T 2, 1+; T 4, 23+; T 5, 1+; O 2, 25–29, 32, 35–36, 39+; O 3, 49+; Ar 1, current; Ar 2, 1+; K 1, 45+; K 3, 27–32, 35–37, 42+; Tn 1, 21+; Tn 2, 39+; Tn 3, 1–17, 22, 27+.

Journal of Nervous and Mental Diseases. 1874. **71.**
V 1, 38+; V 3, 48+; N 2, 1+; S 3, 34–35, 37+; T 2, 2, 5–15, 18–19, 22+; T 9, current; O 2, 35+; Ar 2, 1890–1894, 1918+; K 1, current; K 2, 6–15; K 3, 33–46; Tn 2, 3, 5–9, 11, 15–21, 24–33, 35+; Tn 3, 4–10, 12, 22–31.

Journal of Nutrition. 1928. **2.**
V 2, 1+; V 3, 1+; N 2, 1+; N 3, 1+; S 2, 1+; F 1, 1+; A 4, 1+; L 1, 1+; T 1, 2+; T 2, 1+; O 1, 1+; O 3, current; Ar 1, current; K 3, 1+; Tn 2, 1+.

Journal of Obstetrics and Gynecology of the British Empire. 1902. **37.**
V 3, 31+; N 2, 1+; O 2, 32+; K 1, 36+; Tn 2, 1+; Tn 3, 1–20, 34+.

Journal of Parasitology. 1914. **16.**
V 1, 1+; V 2, 15+; V 3, 1+; S 2, 13+; S 3, 1+; F 1, 14+; L 1, 6+; L 2, 3+; T 1, 1+; T 2, 1+; T 4, 1+; T 5, current; T 9, current; O 2, 6–16; O 3, current; Ar 1, current.

Journal of Pathology and Bacteriology. 1892. **33.**
V 1, 1–4, 12+; V 3, 16+; N 1, 1+; N 2, 1+; S 3, 1+; A 2, 29+; M 1, current; M 2, 15+; T 1, 6–8, 10+; T 2, 1+; T 9, current; O 2, 15+; Ar 2, 2+; K 1, 1+; K 3, 25, 27–28, 30+; Tn 1, 33+; Tn 2, 1+; Tn 3, 1+.

Journal of Pharmacology and Experimental Therapeutics. 1909. **38.**
V 1, 8+; V 3, 1+; N 1, 1+; N 2, 1+; N 3, 1–12; S 3, 2, 13, 15+; F 1, 1+; A 2, 8–14, 16, 18–20, 23–25, 35+; G 5, 1+; T 2, 1+; T 4, 1+; T 5, current; T 9, current; O 1, 21–23, 25, 27, 29+; O 2, 6+; Ar 2, 1–20, 23+; K 1, 1+; K 3, 1–22; Tn 2, 1+; Tn 3, 34+.

Journal of Physical Chemistry. 1896. **4.**
V 1, 1+; V 2, 1+; V 3, current; V 4, 34+; V 7, 24+; V 8, 26+; N 1, 1+; N 2, 1–2, 7, 10+; N 3, 1–4, 30–31; S 1, 1+; S 2, 32+; G 2, 33+; F 1, 33+; A 1, 1+; A 2, 32+; M 1, current; M 2, 19+, L 1, partial set; L 2, 19+; T 1, 1+; T 2, 27+; T 4, 24+; T 5, 1+; O 1, 2–3, 11, 14–16, 18, 20–21, 23+; O 3, 25–28; Ar 1, 1+; K 3, 18–24, 27+; Tn 1, 1+; Tn 3, 28+; Tn 7, 19+.

Journal of Physiology. 1878. **68.**
V 1, 9–13, 36+; V 3, 48+; N 1, 1–35, 41+; N 2, 62+; S 3, 50, 52, 56+; G 1, 32+; F 1, 68+; A 2, 51–52; A 4, 68+; M 1, current; T 1, 1–23, 31–47, 50+; T 2, 1+; T 5, current; T 9, current; O 2, 48–50, 54+; O 3, current; Ar 2, 1+; K 3, 53+; Tn 1, 3–5, 10+; Tn 2, 1+; Tn 3, 1+.

Journal of Pomology and Horticultural Sciences. 1919. **8.**
S 2, 7+; F 1, 1–4 (inc.), 5+; A 4, 5+; L 1, current; O 3, 7+.

Journal of Radiology. 1920. **14.**
V 3, 1+; S 3, 3–6; O 2, 3+; Tn 2, 2–3 (inc.), 6; Tn 3, 1–6.

Journal of Rheology. 1929. **1.**
A 1, 1+.

Journal of Scientific Instruments. 1923. **7.**
F 1, 5+; T 1, 1+; T 5, 1+; Ar 1, current.

Journal of the American Ceramic Society. 1918. **13.**
N 3, 1+; G 2, 1+; A 1, 1+; T 1, 1+; T 6, 11+; O 3, 11+; Ar 1, current; Tn 3, 1+.

Journal of the American Chemical Society. 1879. **52.**
V 1, 1+; V 2, 1+; V 3, 29+; V 4, 21+; V 6, 29–32, 37+; V 7, 6–7, 15+; V 8, 39+; V 9, 22+; N 1, 1–7, 15+; N 2, 18+; N 3, 41+; N 4, 1+; S 1, 1+; S 2, 15+; G 1, 1+; G 2, 1+; G 3, 33+; G 4, 37+; G 5, 30+; F 1, 1+; A 1,

1+; A 2, **27+**; A 4, **9, 11–13, 16–28, 30+**; M 1, **1+**; M 2, **15+**; L 1, **1+**; L 2, **13+**; L 3, **33+**; T 1, **1+** (inc.); T 2, **3+** (inc.); T 3, **26+**; T 4, **15+**; T 5, **1+**; T 6, **43+**; T 7, **37+**; T 9, current; T 10, **1+**; T 11, **36+**; O 1, **1+**; O 2, **47+**; O 3, **1+**; O 4, **27+**; O 5, **49+**; Ar 1, **12+**; Ar 2, **20–34, 44–46**; K 1, **26+**; K 2, **46+**; K 3, **16+**; Tn 1, **1+**; Tn 2, **29+**; Tn 3, **1+**; Tn 5, **1–3, 5+**; Tn 7, **1+**.

Journal of the American Concrete Institute. 1929. **1.**
A 2, **1+**; T 1, **1+**.

Journal of the American Dental Association. 1914. **17.**
V 3, **3+**; T 9, current; K 1, current; Tn 2, **9+**.

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V 1, **26–44**; V 2, **39+**; N 1, **42+**; N 2, **42**; G 1, **29+**; G 2, **40–42**; G 4, **42+**; A 2, **39+**; T 5, **1+**; Ar 1, **1+**.

Journal of the American Medical Association. 1883. **94.**
V 3, **1+**; N 1, **1+**; N 2, **73–92** (very inc.); N 3, **86+**; S 3, **1+**; G 1, **78+**; F 1, **1+**; A 2, **2–5, 8–29, 31–32, 35–37, 39, 46–54, 56+**; M 2, **47–54, 56–67, 70–86, 89+**; L 1, **92+**; L 2, **64–66, 68–70, 87+**; T 1, **54+**; T 2, **1+**; T 4, **48–66, 69+**; T 5, **36+**; T 7, **77+**; T 8, **92–94**; T 9, current; O 1, **79+**; O 2, **1+**; O 3, **76+**; Ar 1, **67+**; Ar 2, **1+**; K 1, current; K 2, **1–31, 34–37**; K 3, **44+**; Tn 1, **76+**; Tn 2, **31+**; Tn 3, **1+**.

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S 2, **1–19**; F 1, **1–19**.

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V 3, **1+**; N 1, **1+**; S 3, **11, 15+**; F 1, **1+**; A 4, **1+**; M 1, current; T 2, **1+**; T 4, **11–15**; T 9, current; O 1, **1–12, 18+**; Tn 2, **1–2, 9+**; Tn 3, **1–11**.

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N 1, **26–32**; A 2, **33–34**; T 5, **21+**.

Journal of the American Veterinary Medical Association. 1877. **76.** **1–47** (1877–1915) as *American Veterinary Review.*
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V 1, **16+**; F 1, **1+**; A 2, **16+**; T 1, **1+**; T 6, **11+**; O 1, **1–8**; O 3, **19+**; Ar 1, current; K 3, **8, 10+**; Tn 1, **1+**.

Journal of the Association of Official Agricultural Chemists. 1915. **13.**
V 3, **1+**; V 8, **8–11**; N 1, **1+**; N 3, **1–10**; S 1, current; S 2, **1+**; G 1, **1+**; G 5, **2+**; A 4, **1–9, 11+**; M 2, **1+**; L 1, **1, 4–7, 9–10**; T 1, **3+**; T 4, **1+**; O 3, **6+**; Tn 1, **1+**; Tn 2, **1+**.

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Journal of the Department of Agriculture of South Australia. 1897. **34.**

V 2, **9–26**; N 3, **25**+; S 2, **24**+; O 3, **25**+; K 3, **1**+.

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V 2, **26**+.

Journal of the Elisha Mitchell Scientific Society. 1883. **45.**

V 1, **30**+; V 2, **4–26** (inc.); V 9, **39**+; N 1, **1**+; N 2, **1–43**; N 3, **38**+; S 2, **41**+; G 1, **35**+; A 1, **1**+; T 1, **1**+ (inc.).

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T 1, **1**+; T 5, **1**+.

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V 2, **9**+.

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V 2, **35**+; A 2, **41**+; K 3, **1**+.

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V 2, **55–56**; L 1, current; T 1, **1**+; T 5, **1**+; O 1, **1, 5, 7–11, 13–16, 19, 22, 30**+; Ar 1, **1**+.

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V 2, **76**+; N 2, **1**+; A 1, **1**+; A 2, **1886, 112**+; L 2, **91–94**; Tn 3, **1**+.

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N 3, **30**+; S 2, **14**+; F 1, **1**+; O 3, **1925**+; K 3, **1**+.

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O 3, current.

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O 1, **1–28.**

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Journal of the Philippine Islands Medical Association. 1921. **10.**

O 2, **5**+.

Journal of the Royal Agricultural Society of England. 1839.

V 2, [3] **75**+; A 4, **49–57, 59–68, 70**+; O 3, **1873, 1885–1889, 1895**+; K 2, **1–33.**

Journal of the Royal Army Medical Corps. 1903. **54.**
V 3, current; N 2, **1+**; T 2, **32+**; T 5, **8+**.

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S 2, **1903–1904;** S 3, **1922+**; T 1, **1914+**; O 1, **1+**; K 3, **1895+**.

Journal of the Royal Sanitary Institute. 1879. **50.**
N 2, **1+**; Tn 3, **45+**.

Journal of the Royal Society of Arts. 1852. **78.**
T 5, **27+**.

Journal of the Society of Automotive Engineers. 1917. **26.**
V 1, **22+**; V 2, **15+**; G 2, **8+**; F 1, **20+**; A 2, **20+**; L 2, **5+**; T 5, **1+**; O 1, **8, 12–15;** O 3, **22+**; O 4, **26+**; Ar 1, current.

Journal of the Society of Chemical Industry. 1882. **49.**
V 1, **3–41, 43–44, 49+**; V 2, **1+**; V 3, **31+**; V 4, **1+**; V 7, **23+**; N 1, **1+**; N 2, **1+**; N 3, **2–35;** S 1, **30+**; G 1, **23+**; G 4, **30+**; A 1, **1+**; A 2, **47+**; A 4, **7+**; M 2, **2+**; L 1, **1–45;** L 2, **1+**; T 1, **1+**; T 2, **1–28;** T 4, **11+**; T 5, **1+**; O 1, **1+**; O 3, **1+**; Ar 1, **1+**; K 2, **26–35, 37–42;** Tn 1, **1+**; Tn 3, **1+**.

Journal of the Society of Dyers and Colourists. **46.**
A 1, **45+**.

Journal of the Society of Glass Technology. **13.**
A 1, **2+**.

Journal of the Textile Institute. 1910. **21.**
S 2, **18+**; O 3, **18+**.

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T 5, current.

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Journal of the Western Society of Engineers. 1896. **35.**
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Journal of Tropical Medicine and Hygiene. 1898. **33.**
N 2, **1+**; S 3, **18–19, 23–24;** T 2, **4+**; T 5, **25+**; T 9, current; O 2, **18+**; Ar 2, **1918+**; K 1, **32+**; Tn 3, **5–14, 16, 18, 20+**.

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V 1, **1+**; V 3, **1+**; N 2, **1+**; S 3, **1+**; A 2, **1, 3+**; T 2, **1+**; T 5, **1, 3–8;** T 9, current; O 2, **1–14, 19+**; Ar 2, **1+**; K 1, **1+**; Tn 2, **1+**; Tn 3, **1+**.

Kali. 1907. **24.**
T 1, **1–7, 14–20.**

Kitasato Archives of Experimental Medicine. 1917.
N 2, **1+**.

Klinische Wochenschrift. 1922. **9.**
V 1, **9+**; V 3, **1+**; N 2, **1+**; S 3, **7+**; T 2, **1+**; K 1, **3+**; K 3, current; Tn 3, **1+**.

Kolloidchemische Beihefte. 1909. **30.**
V 1, **1+**; N 1, **1+**; N 2, **1+**; A 1, **1+**; A 4, **29+**; T 1, **1+**; T 5, **1+**; Tn 3, **1+**.

Kolloid-Zeitschrift. 1906. **50.**
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T 5, **1+**.

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T 5, **1+**.

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T 5, **1+**.
Korrosion und Metallschutz. **6.**
T 1, **1+**.
Krankheitsforschung. 1925. **8.**
K1, **1+**.

Lait, Le. 1921. **10.**
A 1, current; O 3, **1+**.
Lancet. 1823. **1930-I.**
V 1, **1+**; V 3, **1910+**; N 2, **1+**; S 3, **1919+**; F 1, **218+**; A 1, current; A 2, **168+**; A 4, **216+**; T 2, **1837–1840, 1845+**; T 9, current; O 2, **1913+**; Ar 2, **1+**; K 1, **1+**; K 3, **1905–1916, 212+**; Tn 1, **1910+**; Tn 2, **1910+**; Tn 3, **1+**.
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V 2, **35–36, 41+**.
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S 2, **6+**; F 1, **1+**; O 1, **1–3, 5**; O 3, inc. file; K 3, current.
Lubrication. 1912.
V 4, **13+**; V 8, **8+**; M 1, current; T 1, **2, 6, 8+**; T 3, **14+**; T 5, **12+**; T 6, **8+**; O 4, **12+**; Ar 1, **1+**; K 2, **1918–1920**; Tn 1, **8+**; Tn 3, **9+**.
Lumière électrique. 1879–1916.
L 2, **31, 33–34, 36–45, 47–52.**

Malayan Agricultural Journal. 1912. **18.**
N 3, **15+**; M 2, current; O 3, **12+**.
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V 1, **1–45**; V 2, **29–35, 37–42, 48+**; N 1, **36+**; N 3, **42+**; G 2, **31+**; G 4, **39+**; F 1, **45–46, 48+**; A 1, **1+**; A 2, **34–35, 37+**; L 1, **49+**; L 2, **41+**; T 1, **36–45, 47+**; T 4, **34+**; T 5, current; T 6, **47+**; T 10, **36+**; T 11, **22+**; O 1, **1–36, 42+**; O 3, **45+**; O 4, **36+**; Ar 1, **1+**; K 2, **1908+**; Tn 1, **36+**; Tn 3, **47+**; Tn 8, current.
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V 1, **1–63, 65–101, 105–118, 128+**; V 3, **1+**; N 2, **1+**; T 1, **5–8, 10–12, 14, 16–29, 31, 33, 116+**; T 2, **1+**; T 9, current; O 2, **119+**; Ar 2, **1866–1881, 1883–1901, 1916–1922**; K 1, **119+**; K 2, **15–25, 31–40, 43–44**; Tn 2, **119+**; Tn 3, **119+**.
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T 2, **2.**
Melliand (American Edition). 1929. **1.**
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Mellíands' Textilberichte. 1920. **11.**
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N 1, **30–72**; T 1, **38+**; Tn 3, **2–70.**

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T 5, current; O 1, **58**+; Tn 4, **6**+.

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T 1, current; O 3, current.

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N 1, **7**+; S 1, **1925**+; G 1, **4**+; T 1, (a) **9**+; T 5, (a) **1–3, 9, 11**; (b) **2–4**; Ar 1, current.

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G 1, **2–7**; F 1, **1**+.

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V 1, current; L 1, current; T 1, **3**+.

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N 1, **18**+.

Memorias y revista de la sociedad cientifica "Antonio Alzate." 1887.
N 1, **1**+.

Memorie della reale accademia nazionale dei Lincei.
T 5, **1**+.

Merck's Report. 1892. **39.**
V 1, **19–26**; V 2, **30**+; V 3, **21**+; T 1, **1921**+; O 2, **1**+; K 3, current; Tn 1, **30**+; Tn 2, **32**+; Tn 3, **3–24**.

Metal Industry (New York). 1903. **28.**
A 2, **19**+; T 4, **8**+; K 2, **1908–1913**.

Metall und Erz. 1912. **27.**
V 2, **5–9, 18**+; A 1, **1**+.

Metals and Alloys. 1929. **1.**
V 3, **1**+; V 7, **1**+; F 1, **1**+; A 1, **1**+; A 2, **1**+; A 4, **1**+; L 2, **1**+; T 1, **1**+; T 5, **1**+; O 3, **1**+; Tn 1, **1**+.

Mikrochemie. 1923. **8.**
N 1, **1**+; N 2, **1**+; T 1, **1**+.

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O 3, **3**+.

Milchwirtschaftliches Zentralblatt. 1871. **59.**
O 3, **1926**+.

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V 1, **1–17**; V 7, **1**+; N 1, **1–21**; G 4, **1, 12, 15**+; A 1, **1**+; A 2, **1–24** (inc.), **34**+; L 1, **35–37**; T 1, **1**+; T 10, **1**+; O 1, **1–19, 31, 33–34**; Ar 1, current; K 3, **1–15, 17–18, 31, 35**+; Tn 1, **1**+; Tn 6, **1**+.

Mineralogical Magazine.
L 1, **21–22**.

Mining and Engineering World. **1–46.** 1894–1917.
F 1, **35–45**.

Mining and Metallurgy. 1905. **11.**
N 1, **2–4**; A 2, **1**+; L 1, **8**+; T 1, **5**+; O 1, **1**+; O 4, **3**+; K 3, **5–6, 8**+.

Mining Journal (Arizona). 1917.
T 10, **4**+.

Mining Magazine. 1887. **42.**
A 1, **22**+; T 10, **28–39**; O 1, **32–36, 38**+; O 4, **2–17**; Ar 1, current.

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N 2, **1**+.

Mitteilungen aus dem Grenzgebieten der Medizin und Chirurgie. 1896. **41.**
N 2, **1**+; T 2, **19**+.

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V 1, 51+; N 1, 1+; N 2, 1+; T 1, 1+; Tn 1, 1+.

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V 1, 4–6; N 2, 1+.

Moniteur scientifique du Doctor Quesneville. 1857.

N 1, 1857–1926.

Montanistische Rundschau. 1908.

T 1, 7+.

Monthly Weather Review. 1891. **58.**

V 1, 49+; V 2, 23–51; N 2, 53+; S 2, 22+; G 1, 51+; G 4, 50+; F 1, 1+; A 2, 43+; L 1, 1+ (inc.); T 4, 38+; T 5, current; T 6, current; T 10, 40+; T 11, 1911+; O 1, 46, 49+; O 3, 50+; O 5, 55–57; Ar 1, 1+; K 3, 49, 51, 53+; Tn 1, 1+; Tn 2, 53+; Tn 3, current; Tn 4, 1893+; Tn 6, 1+.

Münchener medizinische Wochenschrifte. 1854. **77.**

V 3, 50+; N 2, 1+; T 2, 38+; K 1, current; K 3, 37–41; Tn 3, 33–36, 38+.

Municipal and County Engineering. 1890.

N 1, 66–72; N 2, 65–71; G 1, 1917+; G 4, 7–11, 15, 19, 21–61; A 2, 69+; T 1, 50+; T 4, 54+; T 10, 68–75; O 1, 58–59, 63, 68–70; Ar 1, current; Tn 5, 55+; Tn 6, 56–59, 61–63, 65–67, 69–72.

Municipal Engineering and Sanitary Record. 1874. **85.**

V 1, 7–10; T 2, 23–62; K 3, 14–16, 18–27, 29–30, 48–58, 62–67, 70+; Tn 3, 1–26.

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G 1, 1–5.

Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen. 1894.

T 5, 1+.

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F 1, 60+; Tn 2, 44+ (inc.); Tn 3, 28–32, 34–43, 47–48.

National Petroleum News. 1909. **22.**

A 2, 17+; M 2, current; L 2, 16+; T 1, 16+; T 4, 13+; T 6, 11+; T 10, 14+; T 11, 14+; O 1, 13+; O 3, 19+; O 4, 12+; O 5, 19+; Ar 1, current; K 2, 20+; K 3, current.

Nation's Health. 1919–1927.

V 3, 1+; T 2, 3–9; O 2, 4–8; Tn 2, 1+.

Natural Gas. 1920. **11.**

A 2, 8+; T 6, 1+; T 10, 9+; T 11, 4+; O 4, 2+; K 2, 1+.

Nature. 1869. **125.**

V 1, 97–106, 108–121, 123+; V 2, 112–116, 123+; V 3, 119+; V 4, 17–63; V 6, 1–2, 31–35, 48, 52, 55, 64, 76+; V 8, 1–80 (very inc.); N 1, 1+; N 2, 1–96, 98, 100–112; N 3, 1–100; G 1, 72+; G 4, 93+; F 1, 77–110, 125+; A 1, 1+; M 1, current; L 1, 27–84, 90–101, 104–108, 110–112, 117+; L 2, 1–26, 45+; L 3, 61–70, 121; T 1, 1+; T 3, 69+; T 4, 70+; T 5, 1+; T 11, 79+; O 1, 27–34, 107+; O 3, 1+; Ar 1, current; K2, 9–10, 19+; K 3, 109+; Tn 1, 1–50, 52+; Tn 2, 119+; Tn 3, 1–87, 92–103, 105+.

Naturwissenschaften. 1913. **18.**

V 1, 1+; N 2, 1+; N 3, 12+; T 5, 4+; O 1, 18+.

Neues Jahrbuch für Mineralogie, Geologie, und Paläontologie. 1830. **1930.**

T 1, 1+; O 1, 1–4, A54+; Tn 3, 1831–1920 (inc.).

New England Journal of Medicine. 1828. **202.**

V 1, 200+; V 3, 1+; S 3, 1+; K 1, current; Tn 2, 198+.

New Phytologist. 1902. **29.**

V 1, 1–23, 28+; V 2, 13+; V 8, 19–20; N 3, 20+; G 1, 20+; F 1, 5–8, 24+;

A 4, **16–17, 21+**; L 1, **9–14, 16, 19+**; T 1, **1+**; O 1, **27+**; O 3, **1+**; Ar 1, current; K 3, **21+**; Tn 1, **22+**.

New York Medical Journal. Name changed in 1924 to *Medical Journal and Record.*

A 2, **38–40, 42–68, 83, 90, 95–100.**

New York Produce Review and American Creamery. 1895. **69.**

V 2, **43+**; S 2, **65+**; O 3, **66+**; K 3, current.

New Zealand Journal of Agriculture. 1910.

V 2, **1+**; N 3, **25+**; F 1, **1+**; O 3, **1+**; K 3, **7+**; Tn 1, **24+**.

Norsk Geologisk Tidsskrift. 1905.

T 1, **10+**.

Northwestern Miller. 1873. **161.**

V 5, **156+**.

Nuovo cimento. 1855.

T 5, **1901+**.

Official Gazette of the United States Patent Office. **390.**

N 3, **354+**; S 2, **366+**; G 4, **1+**; A 1, **1+**; A 2, **1+**; L 1, current; T 3, current; T 4, current; T 6, current; T 10, **1+**; T 11, **1+**; O 3, **1910+** (inc.); O 4, **330+**; Ar 1, **1+**; K 2, **1+**; K 3, **113+**; Tn 1, **1+**; Tn 3, current; Tn 4, **116+**; Tn 5, **134+**; Tn 6, **1+**.

Ohio Journal of Science. 1900. **30.**

N 1, **24+**; S 2, **28+**; F 1, **15+**; M 2, **16, 18+**; T 4, **16+**; T 5, **16–21, 23+**; O 3, **23+**; Ar 1, current; K 3, **20+**.

Oil Age. 1910.

L 1, current; T 6, **22–26**; O 3, **27+**.

Oil and Fat Industries. 1924. **7.**

L 1, **1–3** (inc.), **4+**; T 5, current.

Oil and Gas Journal. 1902. **28.**

N 1, **19–26**; N 3, **26+**; A 2, **16–17**; L 2, **25+**; L 1, current; T 1, **1+**; T 4, **1+**; T 6, **9+**; T 11, **23+**; O 1, **23+**; O 3, **23+**; O 4, **9+**; O 5, **25+**; Ar 1, current; Tn 3, current.

Oil, Paint, and Drug Reporter. 1871. **117.**

N 2, **101+**; F 1, **117+**; A 2, **105, 109+**; T 1, **1920+**; T 4, **92–108**; O 1, **99–102**; K 2, **1923+**.

Oil Trade. 1911.

T 1, **15+**; T 4, **10–15**; T 6, **7–18**; O 4, **9–17**; K 3, current.

Oil Weekly. 1916. **56.**

L 1, current; L 2, **45+**; T 1, current; T 4, **16–25, 42+**; T 5, current; T 6, **1+**; O 1, **46+**; O 3, **46+**; O 4, **20+**.

Oversight over det Kongelige Danske Videnskabernes Selskabs Forhandlinger. 1814.

T 5, **1+**.

Paint, Oil, and Drug Review.

A 2, **69–72.**

Paper. **1–35.** 1910–1925.

A 2, **30–32.**

Paper Industry.

L 1, **6+**.

Paper Trade Journal. 1872. **90.**

V 8, current; A 2, **80+**; L 1, **36+**.

Pediatria, La. 1893. **38.**

T 5, **22+**; Tn 3, **1+**.

Pediatria, La (*Revista*). **38.**
Tn 3, **1+.**

Perfumery and Essential Oil Record. 1910. **21.**
N 2, **18+**; F 1, **21+**; O 1, **16+.**

Petroleum Age. 1914. **24.**
A 2, **21+**; T 4, **8–20**; T 6, **15+**; O 1, **9+**; O 4, **13+.**

Petroleum Engineer. 1930. 1930. **1.**
O 4, **1+.**

Petroleum Times. 1919. **23.**
T 5, **3+**; T 6, **10+**; O 1, **5+**; O 4, **13+.**

Petroleum World (London). 1903.
T 6, **24+**; O 5, **14–15.**

Petroleum World (Los Angeles). 1915.
T 6, **10–14**; O 4, **22+.**

Petroleum Zeitschrift. 1905. **26.**
T 1, **1+**; O 1, **12, 17, 19–23.**

Pharmaceutical Journal and Pharmacist. 1841. **124.**
V 3, **101+**; N 1, **1–104**; F 1, **116+**; O 1, **118+**; Tn 3, **68–71, 75–103, 105–108.**

Pharmazeutische Zeitung. 1855. **75.**
F 1, **75+.**

Pharmazeutische Zentralhalle. 1859. **71.**
V 3, **57+**; F 1, **68+.**

Philippine Agricultural Review. 1908. **22.**
V 2, **1+**; N 3, **15+**; S 2, **22+**; T 4, **4+**; K 3, current; Tn 1, **1+.**

Philippine Agriculturist. 1911. **19.**
V 2, **1+**; N 3, **13+**; S 2, **18+**; G 1, **1+**; L 1, **8+** (inc.); O 3, **14+**; K 3, current; Tn 1, **10+.**

Philippine Journal of Science. 1906. **41.**
V 1, **1–5**; V 3, **6+**; N 1, **3+**; N 2, **1+**; S 3, **16–21**; F 1, **24+**; T 1, **1–5**; T 2, **1+**; T 4, **1–5**; T 5, **19+**; O 3, **1–3**; Ar 2, **1923+**; K 3, current; Tn 1, **1+.**

Philosophical Magazine and Journal of Science. 1798. [7] **9.**
V 1, **1–** [6] **46** (inc.); V 6, [6] **45+**; V 8, **65–68**; [n. s.] **1–9, 11**; [n. s.] **1–12**; [3] **26–29**; [4] **1–5**; [6] **15–26, 43–50**; [7] **2+**; N 1, **1+**; N 2, **1+**; N 3, **27+**; S 1, **1913+**; G 1, **229+**; G 2, **21–41,** [7] **1+**; F 1, [6] **10+**; A 1, **1915+**; L 1, L 2, [1] **43–68**; [2] **1–11**; [3] **1–37**; [4] **1–20**; [5] **15–50**; [6] **1–29, 42+**; [6] **27–40**; [7] **3+**; T 1, **1+**; T 4, [6] **33+**; T 5, **1+**; O 1, [5] **1+**; Ar 1, **227–272**; K 3, [6] **1+**; Tn 1, [6] **1+**; Tn 3, [7] **1+.**

Physical Review. 1893. [2] **35.**
V 1, **16–35,** [2] **1+**; V 2, **26–35,** [2] **1–30**; V 8, **30–35,** [2] **1–8, 17+**; N 1, **1+**; N 2, **1+**; N 3, **6–35,** [2] **1–6, 8+**; G 1, **18–35,** [2] **25+**; G 2, **31+**; G 3, **15+**; G 4 [2] **25+**; F 1, **12–13, 20–35,** [2] **1+**; A 1, **1+**; A 2, [2] **31+**; M 2, **15, 17–19, 21–22, 24–28, 30+**; L 1, **27+**; T 1, **1+**; T 4, **9+**; T 5, **1+**; T 7, **25+**; T 11, **30+**; O 1, **1+**; O 3, **15–16, 19-20, 24+**; Ar 1, current; K 3, [2] **1+**; Tn 3, [2] **1+**; Tn 5, [2] **28+.**

Physikalische Berichte. 1920. **10.**
N 1, **1+**; N 2, **1+**; L 2, **2+**; T 1, **1+**; T 5, **1+**; O 1, **1+.**

Physikalische Zeitschrift. 1899. **31.**
V 1, **24**; N 1, **1+**; N 2, **1+**; T 1, **1+**; T 5, **1+**; O 1, **4–20, 22+**; K 3, **27+**; Tn 1, **20+**; Tn 3, **30+.**

Physiological Abstracts. 1916. **14.**
V 1, **1+**; N 1, **1+**; N 2, **1+**; N 3, **15+**; S 3, **7+**; F 1, **5, 7, 10+**; A 4, **7+**;

T 1, **7**+; T 2, **1**+; T 4, **12**+; T 5, **1**+; T 9, current; O 2, **1**+; K 3, current; Tn 1, **1**+; Tn 2, **1**+; Tn 3, **10**+.

Physiological Reviews. 1921. **10.**
V 1, **1**+; V 3, **1**+; N 1, **1**+; N 2, **1**+; N 3, **6**+; S 3, **1–2, 4**+; A 2, **8**+; T 1, **1**+; T 2, **1**+; T 4, **5**+; T 5, **3**+; T 9, current; O 2, **1**+; O 3, **1**+; Ar 1, **1**+; K 1, **1**+; K 3, **1**+; Tn 1, **1**+; Tn 2, **1**+; Tn 3, **1**+.

Physiological Zoölogy. 1928. **3.**
V 1, current; V 2, **1**+; S 2, current; S 3, **1**+; L 1, **1**+; L 2, **1**+; T 1, **3**+; T 5, **1**+; O 1, **1**+; O 3, current; K 3, **1**+; Tn 1, **1**+; Tn 2, **1**+.

Phytopathology. 1911. **20.**
V 2, **1**+; N 1, **1–17**; N 2, **10–16, 18**; N 3, **1**+; S 2, **1**+; G 1, **1**+; F 1, **16**+; L 1, partial set; T 1, **1**+; O 1, **1–3, 6**+; O 3, **1–18**; Ar 1, **1**+; K 3, **1**+; Tn 1, **6–8, 10**+.

Pine Institute of America, Abstracts.
N 1, **1**+; L 1, **4**+; T 1, **3–4.**

Pit and Quarry. 1916. **19.**
N 3, **19**+; A 2, **19**+.

Plant Physiology. 1928. **4.**
V 2, **1**+; N 2, current; N 3, **1**+; F 1, **1**+; T 1, **1**+; T 2, **1**+; T 4, **4**+; O 1, **1**+; O 3, **1**+; K 3, **1**+.

Plant World. **1–22.** 1897–1919. Continued as *Ecology.*
V 1, **20–22**; V 2, **1–22**; N 3, **19–21**; F 1, **1–22**; O 3, **12–14, 17–20**; K 3, **20–22.**

Planta. (*Abteilung E of Zeitschrift für wissenschaftliche Biologie.*) 1925.
O 1, **1**+.

Planter and Sugar Manufacturer. **1–81.** 1888–1929. **1–73** as *Louisiana Planter and Sugar Manufacturer.* Continued as *Facts about Sugar.*
V 2, **76**+; L 1, **1**+; L 2, **38**+; F 1, **27**+; T 4, **72, 75–76**; T 6, **74**+; Tn 1, **76**+.

Plastics.
A 1, **1**+.

Porto Rico Journal of Public Health and Tropical Medicine. **5.** Continuation of *Porto Rico Health Review.*
V 3, **1**+; T 1, **5**; T 2, **1**+; T 5, current; K 3, current.

Posselt's Textile Journal. **1–33.** 1907–1923. Merged into *Textile World.*
S 2, **5–32.**

Power. 1880. **71.**
V 1, **71**; V 2, **15**+; V 5, **60–71**; N 1, **27**+; N 2, **60–63, 65**+; N 3, **23–26, 46**+; S 2, **22**+; G 2, **26**+; G 4, **44**+; F 1, **59–61, 65, 68**+; A 2, **22**+; M 2, **39–49, 51**; L 1, **24–51, 55, 57, 62**+; T 1, **13–18, 24**+; T 4, **43–71**; T 5, **1**+; T 6, **31**+; T 10, **43**+; T 11, **42**+; O 1, **32–35, 38–41, 45–47, 49–53, 55–56, 58**+; O 3, **32, 37, 41–43, 45–59, 61–62, 64**+; O 4, **59**+; Ar 1, **1**+; K 2, **24, 26, 47**+; K 3, **32**+ (inc.); Tn 1, **22–28, 30**; Tn 3, **65**+; Tn 5, **23**+.

Power Plant Engineering. 1896. **34.**
V 2, **24–25**; N 3, **25**+; G 2, **30**+; G 4, **31**+; A 2, **31**+; L 1, current; L 2, **28**+; T 1, **1**+; T 5, **21**+; T 6, **21–24, 30**+; Ar 1, **1**+; K 2, **33**+; Tn 1, **26**+; Tn 3, **28–33**; Tn 5, **27**+; Tn 8, current.

Presse médicale. 1893. **38.**
N 2, **1**+; S 3, **28**+; A 2, **36**+; T 2, **22**+; T 9, current; O 2, **30**+; K 1, **32**+; Tn 2, **28**+; Tn 3, **1**+.

Proceedings of the Academy of Natural Sciences of Philadelphia. 1841.
N 1, **1860**+; G 3, **51–61**; L 1, **1858–1868, 1870–1909**; T 1, **1**+; T 4, **1860–1925**; T 5, **13**+; T 6, **77–80**; O 1, **77–80**; Ar 1, current; K 3, **68–72, 75, 77**+.

Proceedings of the American Academy of Arts and Sciences. 1780. **64.**

N 1, **1+**; L 1, partial set; T 1, **28+**; T 5, **43–48, 50–51, 53+**; O 1, **1+**; Tn 1, **1863–1871, 1873–1907, 1909**; Tn 3, **1–12, 32–44** (inc.).

Proceedings of the American Concrete Institute. 1905–1929.

A 2, **18+**; T 4, **20–25.**

Proceedings of the American Gas Association, Technical Section. 1919.

A 2, **1923+.**

Proceedings of the American Philosophical Society. 1838. **69.**

V 1, **55–57, 65+**; V 2, **60+**; V 8, **28, 37–65**; N 1, **15–67**; G 1, **2–3, 7–16**; [n. s.] **1–10**; F 1, **47–50, 53+**; L 1, partial set; T 1, **2+**; O 1, **65, 67+**; K 3, **60–62, 64+**; Tn 1, **17–23, 25+.**

Proceedings of the American Society for Horticultural Science. 1903.

V 2, **1+**; N 3, **1925+**; G 1, **1906+**; F 1, **1–4, 7, 11+**; L 1, partial set; O 3, **1–25** (inc.).

Proceedings of the American Society for Municipal Improvements. 1894.

T 1, **18–29.**

Proceedings of the American Society for Testing Materials. 1910. **30.**

V 1, **27+**; V 2, **14–27**; N 1, **2, 4+**; S 2, **23+**; G 2, **1+**; A 2, **11+**; L 1, partial set; T 1, **1+**; T 4, **1+**; T 5, **2+**; T 6, **19–29**; O 1, **2+**; K 3, **8–16, 18–28**; Tn 1, **1+**; Tn 3, **3–15.**

Proceedings of the American Society of Civil Engineers. 1873. **56.**

V 2, **22–35, 37–39, 48, 50–53**; N 1, **1–50**; N 3, **51+**; S 2, **33+**; G 1, **1–13, 21–49**; G 2, **22–51**; F 1, **42+**; A 1, **1+**; A 2, **53+**; L 1, partial set; T 1, **1+**; T 5, **1+**; T 6, **39–54**; T 10, **28+**; Ar 1, current; K 2, **20+**; Tn 1, **1+**; Tn 3, **41+**; Tn 5, **31+.**

Proceedings of the Annual Meeting of the Society for the Promotion of Agricultural Science. 1880–1920.

N 3, **1880–1915, 1919–1920.**

Proceedings of the California Academy of Science. 1854.

N 1, **1–16**; G 1, [4] **1+**; L 1, current; T 1, [3] **1–6**, [4] **1–16.**

Proceedings of the Cambridge Philosophical Society. 1843. **26.**

V 1, **25+**; N 1, **21–24**; T 1, **2+**; T 5, **10–22, 24+**; O 1, **21+**; Tn 3, **1929+.**

Proceedings of the Colorado Scientific Society. 1883.

L 1, current; T 1, **4+**; O 1, **3–11.**

Proceedings of the Engineers' Society of Western Pennsylvania. 1880. **46.**

N 1, **36–44**; A 2, **43+**; M 2, **30+**; T 1, **5–10, 22+**; K 3, **15–33, 43+.**

Proceedings of the Imperial Academy (Japan). 1925. **6.**

L 1, **3–4**; T 2, **2+**; T 5, current.

Proceedings of the Indian Association for the Cultivation of Science. 1915.

O 1, **10+.**

Proceedings of the Indiana Academy of Science. 1891.

N 1, **25–35**; T 1, **1891–1897, 1901, 1907–1914, 1916**; Tn 3, current.

Proceedings of the Institution of Civil Engineers. 1837.

V 1, **109–158**; V 2, **201+**; A 2, **187–206**; O 3, **1911+** (inc.); Tn 3, **12–166, 168–169, 197.**

Proceedings of the Iowa Academy of Science. 1887. **35** (1928).

N 1, **1+**; T 1, **1+**; O 1, **2–8, 10, 12–31.**

Proceedings of the Leeds Philosophical and Literary Society; Scientific Section.

V 1, **1+.**

Proceedings of the National Academy of Science. 1915. **16.**

V 1, **1+**; V 2, **15+**; V 8, **7+**; N 1, **1–14**; N 2, **10+**; G 1, **3+**; F 1, **15+**; A 2,

16+; L 1, current; T 1, **1**+; T 4, **1**+; T 5, **1**+; O 1, **1**+; O 3, **2–8, 16**+; Ar 1, current; K 3, **1**+; Tn 1, **1**+; Tn 3, **1**+; Tn 6, **1**+.

Proceedings of the Oklahoma Academy of Science. 1910.
N 3, **1–6**; P 3, **1926**+; O 4, **1**+.

Proceedings of the Physical Society of London. 1874. **42.**
V 1, **41**+; V 2, **21–29**; T 1, **1**+; T 5, **1**+; O 1, **1**+.

Proceedings of the Royal Academy of Sciences of Amsterdam. 1898. **33.**
N 1, **1–20**; T 5, **1**+.

Proceedings of the Royal Agricultural Society of England. 1839.
T 1, **65–74**; O 3, current.

Proceedings of the Royal Institution of Great Britain. 1851.
V 2, **1–20.**

Proceedings of the Royal Irish Academy. 1836.
N 1, **1–6, 24–38**; T 1, **25**+.

Proceedings of the Royal Society of Edinburgh. 1832. **50.**
V 1, **45**+; N 1, **15–48**; N 2, **1**+; T 1, **3**+; T 5, **42**+.

Proceedings of the Royal Society of London. 1800. From 1905 in two sections. **A 126; B 106.**
V 1, **1**+; V 2, **1–75**; N 1, **1**+; N 2, **1**+; N 3, **99**+; S 3, (B) **93, 104**+; G 1, (B) **92**+; G 2, **28**+; F 1, (A) **122**+; A 1, **1915**+; T 1, (A) **1**+; T 2, **76**+; T 5, **1**+; T 8, (A) **1–123**; (B) **1–102**; T 9, current; O 1, **1**+; Ar 1, (A) **76–123**; Ar 2, **1886**+; K 3, (A) **76–78, 80**+; (B) **91–94, 96**+; Tn 3, **1**+.

Proceedings of the Royal Society of Medicine. 1907. **23.**
N 2, **1**+; S 3, **1**+; T 2, **1**+; T 9, current; O 2, **18**+; K 1, **1**+; Tn 3, **8, 10**+.

Proceedings of the Society for Experimental Biology and Medicine. 1903. **28.**
V 1, **19–23, 26**+; V 3, **13**+; N 2, **1**+; S 3, **26**+; F 1, **24–25**; A 2, **24**+; A 4, **27**+; T 2, **16**+; O 2, **26**+; K 3, **9**+; Tn 3, **11**+.

Proceedings of the Staff Meetings of the Mayo Clinic. 1926. **5.**
V 1, current; V 3, **2**+; T 2, **2**+; O 2, **1**+; K 1, current; Tn 2, **2**+.

Proceedings of the University of Durham Philosophical Society. 1896.
T 5, **1–7** (inc.).

Protoplasma. 1927. **9.**
T 1, **1**+; O 1, **1**+; K 1, **1**+.

Public Health Journal. 1910. **21.**
N 2, **1**+; M 1, current; T 1, **8, 11**+; Tn 3, **8–17.**

Public Roads. 1918. **11.**
V 8, **1**+; N 3, **5**+; S 2, **1**+; G 4, **1**+; M 1, current; A 2, **1926**+; A 4, **1**+; L 1, current; T 1, **10**+; T 3, **1–10**; T 4, **1**+; T 5, current; T 6, current; O 3, current; K 2, **1924**+; K 3, **1, 3, 5–9**; Tn 1, **1**+; Tn 4, **1**+; Tn 6, current; Tn 8, current.

Public Works. 1895. **61.**
G 2, **28**+; G 4, **48**+; F 1, **59**+; A 2, **59**+; T 1, **47**+; T 4, **47**+; T 6, **48**+; T 11, **27**+; K 2, **40**+; Tn 5, **24**+.

Pulp and Paper Magazine of Canada. **29.**
A 1, **24**+.

Quarterly Journal of Experimental Physiology. 1908. **20.**
V 1, **3**+; N 2, **1**+; S 3, **1**+; F 1, **15**+; T 2, **1**+; T 5, **12**+; T 9, current; O 2, **1–12, 19**+; Tn 2, **12**+; Tn 3, **2–7, 9, 14**+.

Quarterly Journal of Medicine. 1907. **23.**
V 1, **3**+; V 3, **1**+; N 2, **1**+; S 3, **13**+; T 2, **1**+; T 9, current; O 2, **1–6, 18**+; K 1, **19**+; Tn 2, **1**+; Tn 3, **1**+.

Quarterly Journal of Pharmacy and Pharmacology. 1928. **3.**

S 3, **1+**; T 2, **1+**; O 1, **1+**; Tn 2, **1+**.

Quarterly Journal of the Geological Society. 1845. **86.**

V 1, **83+**; N 1, **1+**; T 7, **82+**; O 1, **70+**; K 3, **84+**; Tn 1, **67–75, 77+**; Tn 3, **1+**.

Quarterly Journal of the Indian Chemical Society. 1924.

T 5, **1+**.

Quarterly of the Colorado School of Mines. 1910. **23.**

N 1, **3–4, 10–11, 18+**; T 1, **2–5**; T 5, current; T 11, **8–23** (inc.); O 3, current; O 4, **24+**; Tn 3, current.

Quarterly of the National Fire Protection Association. 1907. **23.**

Tn 2, **1+**.

Quarterly Review of Biology. **5.**

V 1, **1+**; V 2, **1+**; V 3, **1+**; V 5, **1+**; V 9, **1+**; N 2, **1+**; N 3, **1+**; S 2, **1+**; S 3, **3+**; G 1, **1+**; G 2, **1+**; F 1, **1+**; A 4, **5+**; M 2, **1+**; L 1, **2+**; L 2, **1+**; T 1, **1+**; T 2, **1+**; T 4, current; T 5, **1+**; T 7, **1+**; T 8, **1–2**; O 1, **1+**; O 3, **1+**; Ar 1, **1+**; K 3, **1+**; Tn 3, **1+**.

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V 1, **1+**; V 7, **1+**; N 1, **1+**; N 2, **1–162, 169–180**; S 1, **1923–1929**; A 1, **1916+**; M 2, **91+**; L 1, partial set; L 2, **25–32**; T 1, **1+**; T 5, **1+**; Ar 1, **1–38**; Tn 1, **1+**; Tn 3, **1–90, 96–105, 109+**.

Zeitschrift für Biologie. 1865. **90.**
V 1, **50–66, 68–71, 73+**; N 2, **1+**; T 1, **14+**; T 2, current; Tn 2, **86+**; Tn 3, **1+** (inc.).

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V 1, **15+**; N 1, **1–20**; T 1, **1+**; O 1, **1+**; Ar 1, **1+**.

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N 2, **1+**.

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V 1, **1+**; N 1, **1+**; N 2, **1+**; Al, **1+**; T 1, **1+**; T 5, **13+**; O 1, **27, 29+**.

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N 2, **1–22.**

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N 2, **1+**; T 2, **1–72**; Tn 3, **1+**.

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V 3, **12+**; Tn 2, **46+**; Tn 3, **1+**.

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T 5, **34, 36+**; O 1, **42+**.

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N 2, **1+**; K 1, **1928+**; Tn 3, **1+**.

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V 1, **2–5**; N 2, **1+**; T 2, **82–95, 103+**; K 1, **1928+**; Tn 2, **110+**; Tn 3, **1+**.

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N 2, **1+**; Tn 3, **8+**.

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Tn 3, **3–16, 18–22, 24+**.

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V 7, **1+**; T 5, **65+**.

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T 1, **19+**; T 2, **1+**; O 2, **1+**; K 3, **1+**.

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N 2, **8–10, 12–16, 18–19, 21–24, 28–35, 38+**; L 1, **39+**.

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A 4, **1–7, 9–11, 13–14**; O 3, **14+**.

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V 1, **1+**; V 7, **1–105**; N 1, **1+**; N 2, **1+**; S 1, **1+**; G 1, **1–102**; A 1, **1912+**; M 2, **1+**; L 1, **125–129**; T 1, **1+**; T 4, **66–78**; T 5, **1+**; O 1, **1+**; Ar 1, **1+**; K 1, **1929+**; K 3, **1–107**; Tn 1, **1+**; Tn 3, **1+**.

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V 1, **8–20**; N 1, **1+**; N 2, **1+**; F 1, **53–55, 59+**; L 1, **3–6, 21–24, 27–37, 44–45, 47+**; T 1, **1+**; T 5, **1+**; O 1, **1+**; K 3, **1+**; Tn 3, **54+**.

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V 1, **180+**; V 2, **20–100, 109–113, 115–125, 127+**; V 3, **77+**; N 1, **1+**; N 2, **1+**; L 1, partial set; T 1, **1–109, 111+**; T 2, **1+**; T 5, **1+**; O 1, **1–112**; O 2, **139+**; Tn 2, **163+**; Tn 3, **13–17, 28, 30–43, 49, 54–94, 96+**.

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O 1, **16, 34+**.

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T 5, **1+**.

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N 2, **1+**; Tn 3, **1+**.

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N 2, **1+**.

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N 2, **1+**; O 1, **1+**.

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N 1, **1–10**; N 2, **1+**; T 2, **1–22**; O 2, **1+**; Tn 1, **1+**; Tn 3, **1–15, 17–27, 28, 30–31.**

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V 1, current; T 2, **23.**

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T 1, **136+**; T 5, current.

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F 1, **1+**; O 3, current.

Zentralblatt der experimentelle Medizin. 1912–1914.
N 2, **1–5.**

Zentralblatt für innere Medizin. 1880. **51.**
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N 2, **1–34**; Tn 3, **1–34.**

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V 1, **1+**; N 2, **57, 75+**; T 1, **24+**; T 2, **58**; T 5, current; Tn 2, **53+**.

Government and State Publications

In the following, no attempt has been made to indicate the completeness of the sets of the various publications listed.

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V 2, V 8, N 1, N 2, N 3, F 1, A 2, A 4, L 1, T 4, T 6, T 10, T 11, O 1, O 3, Ar 1, K 2, K 3, Tn 1, Tn 3, Tn 5.

Illinois State Geological Survey, Publications.
V 2, L 1, T 1, T 10, K 3, O 1, O 4, Tn 1, Tn 3.

Illinois State Water Survey, Publications.
L 1, K 2, Tn 1.

Iowa Geological Survey, Bulletins.
V 2, O 3, O 4.

National Advisory Committee for Aeronautics, Publications.
V 2, G 2, G 4, A 2, T 3, T 4, T 5, T 10, O 3, Tn 1.

North Carolina Geological and Economic Survey, Publications.
V 2, N 1, A 1, L 1, O 1, O 4, Tn 3.

Ohio State University, Publications.
M 2, T 5.

Smithsonian Institution, Publications.
V 2, V 8, N 1, S 2, G 1, G 4, F 1, A 2, L 1, T 1, T 2, T 3, T 4, T 5, T 6, T 7, T 10, T 11, O 1, O 2, O 3, Ar 1, K 2, K 3, Tn 1, Tn 2, Tn 3, Tn 4, Tn 6.

United States Bureau of Mines, Publications.
V 2, N 3, S 1, S 2; G 1, G 3, F 1, A 1, M 2, L 1, T 3, T 4, T 5, T 6, T 10, T 11, O 1, O 3, O 4, K 2, Tn 1, Tn 3, Tn 4, Tn 5, Tn 6.

United States Bureau of Standards, Publications.
V 2, V 8, N 3, S 1, S 2, G 1, G 3, F 1, A 1, M 1, M 2, L 1, T 1, T 3, T 4, T 5, T 6, T 10, T 11, O 1, O 3, K 2, K 3, Tn 1, Tn 3, Tn 4, Tn 5, Tn 6.

United States Department of Agriculture, Publications.
V 1, V 2, V 5, V 8, N 1, N 3, S 2, G 1, G 3, G 4, F 1, A 2, M 2, L 1, T 1, T 2, T 3, T 4, T 5, T 6, T 8, T 10, T 11, O 3, Ar 1, K 2, K 3, Tn 1, Tn 3, Tn 4, Tn 5, Tn 5.

United States Geological Survey, Publications.
V 2, V 8, N 1, N 3, S 2, G 1, G 2, G 3, G 4, F 1, A 2, M 2, L 1, T 4, T 5, T 6, T 8, T 10, T 11, O 1, O 3, O 4, Ar 1, K 2, K 3, Tn 1, Tn 3, Tn 4, Tn 6.

United States Public Health Service, Publications.
V 3, V 8, N 1, N 3, S 2, S 3, G 1, G 3, G 4, F 1, A 2, M 1, L 1, T 2, T 3, T 4, T 5, T 6, T 8, T 10, T 11, O 1, O 2, O 3, Ar 1, Ar 2, K 1, K 2, K 3, Tn 1, Tn 2, Tn 3, Tn 4, Tn 6.

United States National Museum, Proceedings.
V 2, V 8, A 2, M 2, L 1, T 1, T 5, T 10, T 11, O 1, O 3, Ar 1, K 2, K 3, Tn 1, Tn 3, Tn 4, Tn 6.

United States Tariff Commission, Tariff Information Series.
V 2, N 1, N 3, S 2, G 1, G 4, F 1, A 2, L 1, T 3, T 4, T 10, T 11, O 1, O 3, Ar 1, K 2, Tn 1, Tn 3, Tn 4.

University of California, Publications.
V 2, N 1, S 2, G 1, A 2, L 4, T 1, T 2, T 5.

University of Illinois, Publications.
N 1, S 2, F 1, A 2, M 2, L 1, T 1, T 2, T 5, T 10, T 11, O 3, Ar 1, K 2, Tn 1, Tn 5.

University of Kansas, Publications.
O 3.

University of Oklahoma, Bulletin.
O 1, O 3.

University of Pennsylvania, Publications.
N 1, T 1, K 2.

University of Texas, Bureau of Economic Geology and Technology, Bulletins.
L 1, T 1, T 3, T 4, T 5, T 6, T 8, T 10, T 11, Ar 1, K 2, K 3, Tn 1, Tn 3.

Standard Reference Books

The following libraries have complete sets (or practically so) of the following reference works.

Abderhalden, *Biochemisches Handlexikon.*
V 1, N 2, G 3, T 2, T 5, K 3, Tn 2, Tn 3.

Abderhalden, *Handbuch der biologischen Arbeitsmethoden.*
V 1, N 2, N 3, G 1, G 3, T 1, T 5, Tn 2.

Abegg and Auerbach, *Handbuch der anorganische Chemie.*
V 1, V 2, V 7, N 2, G 2, T 1, T 5, O 1, Ar 1.

Beilstein, *Handbuch der organischen Chemie.*
V 1, V 2, V 4, V 7, N 1, N 2, N 3, N 4, S 1, S 2, G 1, G 3, F 1, A 1, A 2, M 2, L 1, L 2, T 1, T 2, T 4, T 5, T 8, O 1, O 3, Ar 1, K 1, K 3, Tn 1, Tn 3.

Chemical Society (*London*), *Annual Reports.*
V 1, **1+**; V 4, **1+**; V 7; N 1, **1–12, 14, 21+**; N 2, N 3, **9–12**; N 4 (inc. set); S 1; S 2; G 3; F 1; A 1; A 2; M 2; L 1; T 1, **12+**; T 2; T 4, **1–21**; T 5; O 1; O 3, Ar 1; K 1; Tn 1; Tn 3; Tn 4.

Dammer, *Handbuch der anorganischen Chemie.*
V 7, N 1, M 1, M 2, L 1, T 1, Ar 1, K 3.

Gmelin's Handbuch der anorganischen Chemie.
V 1, V 2, V 7, N 1, N 2, N 3, S 1, G 2, M 2, T 1, T 4, T 5, O 1, Ar 1, K 3, Tn 3.

Hoffman's Lexikon der anorganischen Verbindungen.
V 7, N 2, T 1, T 5, Ar 1.

International Critical Tables.
V 1, V 2, V 3, V 4, V 6, V 7, V 8, N 1, N 2, N 3, N 4, S 1, S 2, G 1, G 2, G 3, G 4, F 1, A 1, A 2, A 4, M 1, M 2, L 1, L 2, T 1, T 2, T 4, T 5, T 6, O 1, O 3, O 4, O 5, Ar 1, K 1, K 3, Tn 1, Tn 2, Tn 3, Tn 7.

Landolt and Börnstein, *Physikalisch-chemische Tabellen.*
V 1, V 2, V 3, V 7, N 1, N 2, N 3, S 1, S 2, G 1, G 2, G 3, F 1, A 1, A 2, M 1, M 2, L 2, T 1, T 2, T 4, T 5, T 8, O 3, Ar 1, K 1, K 3, Tn 1, Tn 3.

Mellor, *Comprehensive Treatise on Inorganic and Theoretical Chemistry.*
V 1, V 2, V 3, V 7, V 9, N 1, N 2, N 3, S 1, S 2, S 3, G 1, G 2, G 3, F 1, A 1, A 2, A 4, M 2, L 1, L 2, T 1, T 2, T 4, T 5, T 6, T 8, O 1, O 2, O 3, O 4, Ar 1, K 1, K2, K 3, Tn 1, Tn 3, Tn 5, Tn 6, Tn 7.

Meyer-Jacobsen, *Lehrbuch der organische Chemie.*
V 1, V 4, V 7, N 1, N 2, S 1, G 2, F 1, A 1, M 2, L 1, T 1, T 2, T 4, T 5, O 1, O 3, Ar 1, K 1, K 3, Tn 1.

Oppenheimer, *Handbuch der Biochemie der Menschen und der Tiere.*
N 2, T 2, Tn 2.

Richter, *Lexikon der Kohlenstoffverbindungen.*
V 1, N 1, N 2, S 1, G 1, G 3, F 1, A 1, M 2, L 1, T 1, T 2, T 4, T 5, O 1, O 3, Ar 1, K 1, K 3, Tn 1, Tn 3.

Society of Chemical Industry (London), Annual Reports.
V 7, N 1 (**2–5, 7, 9–13**); N 2, N 3 (**1–3**), N 4 (inc.), S 1, G 3, A 1, M 2(inc.), L 1, T 1 (**2–9, 12–14**), T 5, O 3, K 3.

Stelzner, *Literatur-Register der organischen Chemie.*
V 1, N 1 (**1910–1918**), N 2, A 1, M 2, T 1, T 2, T 5, Ar 1, K 1, K 3, Tn 1, Tn 3.

Tables annuelles de constantes et données numeriques de chimie, de physique et de technologie.
V 2, V 7, N 2, S 1, S 2, A 1, M 2, L 2, T 1, T 5, Ar 1, Tn 2, Tn 3.

Thorpe, *Dictionary of Applied Chemistry.*
V 1, V 2, V 3, V 5, V 6, V 7, V 8, N 1, N 2, N 3, N 4, S 1, S 3, G 2, G 3, G 4, F 1, A 1, A 2, M 1, M 2, L 2, L 3, T 1, T 2, T 3, T 4, T 5, T 6, T 8, T 10, O 1, O 2, O 3, O 4, O 5, Ar 1, K 1, K 2, K 3, Tn 1, Tn 2, Tn 3, Tn 4, Tn 5, Tn 6, Tn 7.

Ullmann, *Enzyklopaedie der technischen Chemie.*
V 1, N 1, N 2, M 1, T 1, K 3, Tn 3.

Watt, *Dictionary of Chemistry.*
V 1, V 2, V 4, V 6, V 7, V 8, V 9, N 1, N 2, N 3, S 2, G 3, G 4, F 1, A 1, M 1, M 2, L 1, L 2, L 3, T 1, T 3, T 4, T 5, T 6, O 1, O 2, O 3, Ar 1, K 1, K 2, K 3, Tn 1, Tn 2, Tn 3, Tn 6, Tn 7.

Weyl-Houben, *Methoden der organischen Chemie.*
V 1, V 2, V 7, N 2, N 3, F 1, M 2, L 1, T 1, T 2, T 4, T 5, O 1, Ar 1, K 1, Tn 1, Tn 3.